Tilling the Soil in Tanzania: What Do Emerging Economies Have to Offer?

Thesis

Tilling the Soil in Tanzania: What Do Emerging Economies Have to Offer?

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ABSTRACT

Close to 70% of Tanzanian farmers are small scale resource–poor subsistence operators, cultivating an average of less than 1 to 3 hectares of mainly rain-fed land, deteriorated by continuous cropping and lack of fertility management. In the farmers' effort to move up the commercialisation continuum and alleviate poverty through increased output and incomes, innovation and technical change is key. However, liquidity constraints and prohibitive prices have in the past discouraged farmer investment in capital goods (power tillers and tractors). This is a limiting factor for increased cropping area and timeliness of operation which has the potential to positively affect crop output and incomes. In the face of these difficulties, the farmer is prepared to trade-off quality and variety, for relatively low priced capital goods, provided they are good enough and rely less on heavily built infrastructure. In recent decades, the capital goods market for power tillers and tractors has become dynamic with respect to cost, quality and origin of production. With new entrants like China, India and Pakistan joining Western Europe, USA and Japan in the supply of farm machinery, the range of choice for the Tanzanian farmer is increasing. Chinese, Indian and Pakistani power tillers and tractors have some distinctiveness in their engineering, acquisition cost, operational cost and their supply chains which may be useful in more ways to the small farmer in Tanzania. This thesis appraises the pro-poor nature of emerging economy tillage capital goods, placing particular emphases on how an optimal technological choice is made. It examines the role that cost innovators' from emerging economies (China/India/Pakistan) are playing in meeting the farmers' choice objective particularly with regard to cost, labour intensity and scale of operation. In as far as Tanzanian farmers are concerned the study discusses the role that local institutions can play to enhance choice, access and efficient use of such capital goods for higher productivity which may translate into increased incomes. The study draws on both qualitative and quantitative data to compare advanced country tractors and power tillers with those from emerging economies and finds that; First, aid/government support, trade and FDI/licencing are key conduits for technology imports into Tanzania. However, trade has been very important for emerging economy machines whilst aid/government support has been found to be key for advanced country machines. Second, in terms of penetration and extent of use among Tanzanian farmers emerging economy machines are more popular than advanced country ones when it comes to power tillers. Nevertheless, the total stock of advanced country tractors in Tanzania are known to be larger than emerging economy ones; though we are recently witnessing a recent rapid increase in the former than the latter. Third, advanced country machines are generally superior in terms of engineering performance and work efficiency when compared with emerging economy ones. That said, it is worth noting that the advanced country machines are capital intensive and involve higher maintenance costs because of higher spare parts and repair cost. Finally, emerging economy machines are more pro-poor than matured market ones since they create more opportunities for employment and capability building among capital constrained users and dealers.

In memory of grandma, Nana Ama Pokua, you taught me how to spell my name!

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2WD	Two Wheeled Drive
4WD	Four Wheel Drive
AICD	Africa Infrastructure Country Diagnostic
AITF	Agricultural Input Trust Fund
AMECCO	Changzhou Agricultural Machinery and Equipment Company Ltd of China
BOT	Bank of Tanzania
BCAs	Benefit-Cost-Analyses
CAMARTEC	Centre For Agricultural Mechanisation And Rural technology
CRDB	Cooperatives Rural and Development Bank
EE	Emerging Economies
EP	Engine Propelled
EU	European Union
FWA	Front Wheel Assist
FWD	Four Wheel Drive
GDP	Gross Domestic Product
IBRD	International Bank of Reconstruction and Development
ICRA	Investment Information and Credit Rating Agency of India Limited
IFAD	International Fund for Agricultural Development
IMF	International Monetary Fund
LFS	Labour Force Survey
MAFAP	Monitoring Food and Agricultural Policies in Africa
MAFF	Ministry of Agriculture, Forestry and Fisheries (Japan)
MAFC	Ministry of Agriculture, Food Security and Cooperatives
MDG	Millennium Development Goals
MM	Matured Market Economies
MoFEA	Ministry of Finance and Economic Affairs
MP	Motion Propelled
NBC	National Bank of Commerce
NBS	National Bureau of Statistics
NMB	National Microfinance Bank
OC	Operating Conditions
SCCULT	Savings and credit Cooperative Union of Tanzania
SSA	Sub-Saharan Africa
TRAMA	The Tanzania Tractor Manufacturing Assembly Plant
TAFE	Tractors And Farm Equipment Limited
UNECA	United nations Economic Commission for Africa
UNIDO	United Nations Industrial Organization
UN-OHRLLS	United Nations Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States
URT	United Republic of Tanzania
USA	United States of America
USCB	United States Census Bureau
USDA	United States Department for Agriculture

Chapter 1 : Introduction

1.1 The economic impasse

Between 2001 and 2007, GDP growth in Tanzania averaged 7%, peaking at 7.8% in 2004. This made Tanzania one of the fastest growing economies in sub-Saharan Africa (SSA). Tanzania Mainland total GDP in 2007 was 51% higher in real terms than in 2001 (Atkinson & Lugo, 2010). During the same period however, the incidence of basic needs poverty in Tanzania, using the head count poverty index, stood at 36.7% in 2001 and 33.6% in 2007. Food poverty also remained relatively static, 18.7% (2001) and 16.6% (2007) (NBS, Tanzania in Figures , 2010). Econometric estimations suggest that the marginal decline in poverty observed over this period is simply due to sampling variability; poverty did not decline at all (Mkenda et al., 2009). This has led some scholars to argue that Tanzania is off-track in reaching the MDG target of halving poverty in 2015 (Hoogeveen & Ruhinduka, 2009). Instead of poverty reduction, this impressive growth has rather led to increased income inequality (Mkenda et al., 2009).

Many economies are growing while at the same time livelihoods are not improving for those at the bottom of the income pyramid (Fan et al., 2010). To address this economic impasse of high-growth high-poverty, the sources and the beneficiaries of growth require examination. The Tanzanian economy is dominated by three major sectors: agriculture, industry and services. In 2009, when agriculture's share of GDP stood at 25%, it employed nearly 74% of the workforce. Services and industry on the other hand had a share of 45% and 20% respectively; altogether employing 25% of the workforce (MoFEA, 2009). In 2001, when the GDP of Tanzania grew by 6%, the agricultural sector (a major employer) grew by a little over 4%. In 2007, the margin widened, with the economy growing over 7% while agriculture remained below 4% (NBS, 2010). Thus, though an important sector in terms of employment creation, growth in the agricultural sector stagnated in the noughties. Undoubtedly, without growth, households depending on agriculture will be poor, barring any external transfers. It thus comes as no surprise that in 2007, 38.7% of the population whose primary source of cash income came from agriculture were poor, a slight decline from the 2001 figure of 39.9%. Of all the poor in Tanzania, 81% and 74% constitute those engaged in agricultural activities in 2001 and 2007 respectively (NBS, 2009).

1.2 Agriculture as a strategy for poverty reduction

The low agricultural growth in Tanzania is underpinned by over-reliance on unpredictable natural precipitation, minimum use of improved seeds and fertilizer and the use of manual labour (MAFAP, 2013). Coupled with inefficient allocation and use of scarce resources across and within sectors of the economy, agriculture has remained underdeveloped. A cross country study in Africa suggests that paying attention to agriculture as an engine of growth has a higher potential for reducing poverty than other mechanisms (Diao et al., 2007).

The consensus is thus to focus on the importance of agriculture and rural development as a viable response mechanism to new challenges for growth and poverty reduction (Sarris, et al., 2006; Fan et al 2010). Transforming the agricultural sector into a viable growth pathway requires appropriate mechanisation technologies in the context of the rural poor to augment other inputs (Biggs et al., 2011). Thus any attempt to gradually replace hand hoe and oxen plough which dominates Tanzanian agriculture with mechanical power where possible to do so, is essential. This could help reduce the challenges posed by manual labour use: limitations on area cultivated per season, inadequate seed bed preparation and timeliness of tillage operations (IFAD, 1998).

1.3 Technology: a necessary tool for agricultural sector growth

Technological progress and innovation determine productivity, and hence the rate of growth (Solow, 1956). Technological progress is also dependent on both physical and soft infrastructure, which is sometimes unevenly spread within and across countries of the world. The physical environment and social context within which technology evolves also shapes the nature and character of the technology (Kaplinsky, 2009). Farm mechanisation technologies also operate under a similar framework. What constitutes appropriate mechanisation technology in a developing country context can sometimes overlap, conflict and confuse: becoming a source of debate for agricultural engineers and agricultural economists (Eicher & Baker, 1982). However, the potency of mechanical power in contributing to agricultural productivity, especially at the land preparation stage has not been challenged (FAO/UNIDO, 2008). Despite this potential, mechanical power use on Tanzanian farms has not seen significant expansion in recent decades.

The most common forms of mechanical power on farms are two-wheeled or walk- behind tractors (power tillers) and four-wheeled tractors. Current estimates suggest that out of every 100 farms in Tanzania, only 16% use power tillers or tractors for tillage. The remaining 84% farms are tilled with hand hoe and oxen plough. Thus the agricultural landscape is dominated by hand hoes (Menenwa and Maliti, 2010; Lyimo, 2011). Farmers benefiting from the use of mechanical power (tractors and power tillers) are mostly large scale farms constituting 8.5% of the area cultivated by all farms in the country (URT, National Sample Census of Agriculture 2007/08: Large Scale Farms, 2012) and producing mostly commercial crops for export or relatively richer small scale farms cultivating high value crops. This clearly indicates that small scale food crop producers are not using the few tractors available. Without intervention (policy wise), there is little evidence that the status quo will change especially when farming investment finance is scarce among rural dwellers.

Over 60% of all rural households do not have access to any form of formal financial services (Jessop, et al., 2012). Thus, resources for investment are scarce. This makes it difficult, especially for small farmers to purchase farm inputs generally, and tillage equipment in particular. Only 15.4% of all commercial bank loans went to Tanzanian farming households in 2011 (Bank Of Tanzania, 2012). This represents less than 20% of farmers' demand for credit per annum. The gap between demand and supply is not met by farm profits either. A study by Ellis et al., (2010) investigating the impact of access to financial service on household investment revealed that in Tanzania, only 3% of respondents in their sample saved towards the purchase of farm implements. The rather lean farm profits, resulting mainly from smaller farm sizes and low productivity are competed for by household consumption and savings. In most instances, consumption triumphs over savings, leaving very little for investment. Thus, in the midst of a high population growth rate (2.3% per annum for rural households), requiring increased food production, there is limited use of modern agricultural technologies including mechanisation (power tillers and tractors), which are essential for any modernized farming.

1.4 Traditional north and indigenous technologies

In the backdrop of the constraints described in the previous section, power tillers and tractors, like other capital goods on the Tanzanian market have in the past predominantly come from EU, USA and Japanese producers (matured markets). Thus for most companies or planning agencies considering the start of a production process or replacing equipment, the choice then belonged to a spectrum of advanced country technologies. Historically, machines from these matured markets, hereafter MM, were described as efficient. There was the notion that these 'efficient' techniques from advance countries maximizes output on large scale, spurs economic growth and development for both developed and developing countries. With time, it became clear that this conception of efficiency was flawed, in that this pattern of technological development was associated with undesirable social and environmental developments (Kaplinsky, 1990). Driven by institutional R&D of industrially advanced northern countries, innovation and technological progress did not cater for all the needs of the developing south (emerging economies, hereafter EE). Especially in the 1970s and 1980s, these innovations rather created a state of technological dependence (Soete, 2009).

Empirical studies have shown that imported techniques from MMs were not always suitable for the developing country context. In terms of scale, labour requirements, availability of accompanying infrastructure and distribution of benefits so derived were modelled around the endowments of the developed world (Stewart 1977; Kaplinsky 1990). These efficient technologies also came at a higher cost, reflecting the income levels of advanced country users. In the face of inadequate finance and high cost of products, only a few users could afford power tillers and tractors. Consequently, whereas, the latent demand for tractors in Tanzania is between 1500 and 1800 units; and that of power tillers is estimated at 1500 and 2000 units per annum; between 2005 and 2009, supply rarely reached a third of this because of lack of effective demand (Lyimo, 2011).

Alongside the so called efficient technologies evolved an indigenous set of technologies which were considered to be inefficient, small scale and usually locally produced with little or no formal research. Some of these indigenous technology developments stem from the appropriate technology movements. Underpinned by acts of charity, they did not suffice either. Investment in animal draft power for instance, has diminished overtime. To meet desired development targets, Gurak (2003) notes that developing countries had two options: first encouraging indigenous technological development and second transferring already existing technologies from MM. The question which kept many writers busy in the 70s and 80s was which of these sources will be an appropriate one for the developing world, especially sub-Saharan Africa (SSA)? However, both sources had a limited impact in transforming the agricultural sector in SSA into an engine of growth and poverty reduction, including the Tanzanian case.

1.5 Filling the gap

Recent developments in the world economic order has seen the rise of emerging economies like China and India (EE) as well Brazil, Turkey and Pakistan. The noughties saw a substantial increase in the share of global manufacturing value added in low income countries in general and in China in particular (Kaplinsky, 2011). By 2000, more than one-fifth of global R&D was located in the emerging economies (Hollander, 1965; Soete, 2010; Kaplinsky 2011). This increase is of major significance given the estimated share in 1970 of only 2% (Singer et al, 1970; Kaplinsky, 2011). An increasing share of this dispersed R&D occurred as a result of outsourcing by global Trans National Corporations (TNCs), particularly to EEs (Bruche, 2009). The EEs possess resource endowments and income levels similar to those of other developing countries in SSA such as Tanzania. There is thus, some justification to believe that technologies they produce for themselves may as well be suitable for the operating conditions of other developing countries, including Tanzania. For instance, trends in average farm sizes across continents as shown in Table 1.1 suggests that holdings in Africa were more similar to those in Asia than they are to the Americas or Europe. The average farm sizes for Africa and Asia are both 1.6 hectares. Consequently, it is possible that production techniques appropriate for Asian farms (especially the EEs) may more readily fit the SSA terrain of which Tanzania is part.

Table 1.1: Approximate farm size by world region

World region	Average farm size, hectares
Africa	1.6
Asia	1.6
Latin America and the Caribbean	67.0
Europe [a]	27.0
North America	121.0

Source: von Braun 2005. [a] Data include Western Europe only

Historically, China and India have interacted with Tanzania through Friendship Agreements at the diplomatic level and through cultural and knowledge exchange as a result of migration. These relationships have helped establish trade routes between Tanzania and these EEs. In recent years therefore, there has been a rise of both consumer and capital goods on the Tanzanian market from China and India in particular.

Machines from the EEs compete with MM products, and most importantly meet the demand and purchasing power of low income groups in Tanzania. Other products from Brazil and Turkey are much more like MM ones in character, sometimes possessing state-of-the-art technologies of global manufacturers and at other times of reduced quality. Products from EEs are usually not of very high quality, but they are regarded by some consumers as “good enough”. In a broader sense however, in meeting the needs of lower income groups who might have otherwise been neglected in the value chain, the usefulness of EE machines cannot be overlooked in Tanzania.

The recent trade boom between EEs and Tanzania has also been reflected in the tractor and power tiller market. The rise and presence of EEs in the Tanzanian market provides a wider scope for the selection and use of power tillers and tractors by Tanzanian farmers. Thus, in addition to the advanced country and indigenous technologies, now farmers have a third alternative from EEs. The question is how might this new market dynamic affect technique choice of the decision maker (the farmer)? And again how could this choice influence productivity (and therefore growth) at the farm level and distribution of the gains across low income groups within the value chain?

This central theoretical issue is explored in this thesis through a comparative study of power tillers and tractors from MMs and EEs being used in Tanzania with a view to addressing the tractorisation debate and contributing to the appropriate technology literature. The thesis isolates the engineering and economic distinctiveness of the technologies from the two sources (MM and EE), and the extent to which one is pro-poor in more ways than the other along the chain of technology transfer, diffusion and use. The overarching research question is: *Do MM and EE tillage technologies have different characteristics under Tanzanian conditions*?

Specifically, the thesis attempts to respond to four research questions using small, medium and large scale farms operating under five different agro-economic conditions in Tanzania as a focusing device:

1. What is the mode of transfer and diffusion of MM and EE tillage technologies in Tanzania?

2. To what extent are MM and EE tillage capital goods being used in Tanzania?

3. In what ways are MM tillage technologies distinctive from EE ones?

4. Do the inherent distinctive characteristics (if any) of EE tillage technologies help address the needs of resource constrained farmers and other participants in the value chain and hence reduce poverty?

1.6 Organization of the thesis

To answer the above research questions**, Chapter 2** discusses Tanzania in the context of rural development, agriculture and mechanisation. Here, the importance of agriculture in the Tanzanian economy and how it could serve as a wealth creation tool is emphasised. The role that mechanical technology can play is also explored. An overview of the international tractor market is also undertaken to help our understanding of where mechanisation technologies are developed and sold and the marketing models adopted. After a historical overview of the global development of farm mechanisation, the most important players in terms of demand and supply are characterized. Attention is paid to the different regions of the world where tractors are produced and sold and the characteristics of the farmers and farms. At the end of Chapter 2, an examination of which sources of supply are more similar in character as the Tanzanian terrain is also undertaken.

In **Chapter 3**, literature related to technique choice, technology transfer and diffusion are surveyed. The evolution of technological choice on the global stage between advanced and developing countries since the 1970s are tracked. Efforts to improve the diffusion and use of technologies by low income groups are also discussed with a view of establishing why different waves of technology transfer could not deliver the promised gains. Empirical studies conducted in the 1960s and 1970s to establish the viability of the different trajectories of technical choice is also reviewed. To bring the literature survey home to our discussion of current trends on the world stage, the emergence of the Emerging Economies and their associated cost innovations are also examined in the context of possible contribution to Tanzanian agriculture.

In **Chapter 4**, the methods used in collecting and analysing the data in this study are discussed. Here the sampling procedures used in selecting each group of respondents at the various links of the value chain are presented. Characteristics of the study sites are also presented in brief and then the methods adopted in analysing each set of data are also explained. **In Chapter 5**, an attempt is made to define what an appropriate choice of tillage technology is for small, medium and large scale farmers cultivating different crops under different soil and water supply regimes. This exercise is carried out by first establishing who the farmers under consideration are; what they do; how they do it; and what technology alternatives are available to them for these assignments.

Chapter 6 establishes the value chain that is responsible for the transfer and diffusion of these technologies and the role various actors play and the mechanisms these actors employ to accomplish their roles. The discussion for tractors is organized to capture the pre- and post- Structural Adjustment days: with different market regions during the two periods, the discussion throws light on how participants and their activities in the value chain are changing over time. In **Chapter 7**, a critical examination of distinctiveness of the various strands of techniques is done by comparing their engineering and quality features. This then naturally leads us into a discussion of the coefficients of production. These productivity ratios are in most cases organized around the output generated and labour and capital consumed per season. To get an understanding of how well a particular category of technology is doing or otherwise for a technical efficiency measure, their performance are ranked. To further enhance our technique choice tools, the Net Present Values (NPVs) of costs and benefits streams associated with each category of technology is calculated and compared. In addition, a sensitivity analyses are carried out on the assumption that current government subsidies on power tiller and tractor technologies are removed: this is to ascertain the effect of subsidy removal on the benefit-cost ratios.

Chapter 8 examines why users sometimes choose inefficient techniques. To link the discussion to inclusive innovation through growth and distribution to excluded portions of society, we examine the extent to which the choice of various techniques impact on employment and output and who benefits from these. For instance we discuss the growth in farm size and which types of crops (cash/food security crops) which benefit most from the technology. The environmental and health impacts are then considered: emphases is laid on the release of CO_2 through smoke, noise pollution, scrap metal waste, ergonomics and potential injuries that users could sustain during usage. In **Chapter 9**, findings from the thesis are summarised and implications drawn for policy, future research and the extent to which they can be generalized for other sectors of the economy.

Chapter 2 : Tanzania, Mechanisation and Rural Development

2.1 Introduction

Agricultural growth, rural development and employment creation are policy fundamentals that caught and engaged the attention of many African governments in the post-independence era. These policy foundations did not however carry a similar impetus after structural adjustment days. With political independence, many SSA states were hopeful that they would attain economic independence in the ensuing years. Unfortunately, flawed understanding of the order of world trade and economies embedded in rudimentary agriculture shattered such hopes. In addition, lack of a reliable supply of skilled labour, entrepreneurial scarcity, inadequate financing of the private sector and government control of productive sectors, coupled with political instability were detrimental. The non-existence of appropriate technology or inability to make a right choice from a range of technologies has also contributed to the lack of progress.

The economic structure designed and implemented during the colonial days did not change after independence. SSA economies were peripheries of European colonisers (Rweyemamu, 1973). Consequently, this created a state of technological dependence, mostly through trade and aid (Stewart, 1977). SSA countries continued to rely on trade links with Europe, mainly in agricultural commodities and minerals, as the main source of exchange (Vickers, 2011). Global recession in the 1970s and particular problems encountered by different countries stifled economic activities and exacerbated poverty. Many SSA countries were left indebted to multilateral and bilateral financiers and could not meet the payment schedules of such loans (UNECA, 2011). Through IMF and World Bank prescriptions, a policy of liberalisation and an adjustment of the general economic structure was adopted and pursued by some African countries in the 1980s and 1990s (Mohan, 2000). What later became known as the "Washington Consensus" in the late 1980s was a set of policies that underpinned economic adjustments in the developing world, notably Latin America and SSA, and supported by Western governments to promote economic liberalization.

The main proponent of the consensus included Fiscal Discipline, Reordering Public Expenditure Priorities, Tax Reform, Liberalizing Interest Rates, A Competitive Exchange Rate, Trade Liberalization, Liberalization of Inward Foreign Direct Investment, Privatization, Deregulation and Property Rights (Williamson, 1990). There were costs and benefits accruing to different countries in different ways. However the challenges pertaining to employment and poverty remained. This led to the Millennium Development Goals (MDGs) of the United Nations at the turn of the century. Among other things, the MDGs targeted improvements in education, health and poverty reduction within the populations of the bottom billion of the global income pyramid.

Efforts to reach the MDG targets have been pursued in many SSA countries but it is believed that those related to halving poverty by 2015 are likely to be missed. Tanzania, an example of an independent African country that has distinguished itself as a safe haven for peace and stability in the past 50 years has not performed differently from other SSA countries when it comes to poverty reduction (Erickson, 2012). Despite the political stability enjoyed by the country, general welfare of its ever growing and predominantly rural population engaged in agriculture has not improved significantly.

Though agriculture is an important economic activity for the rural population in Tanzania, it has seen slow growth in terms of biological, chemical and mechanical technology transformation (Pfitzer, Krishnaswamy, & Genier, 2009). The mechanical aspect is the most neglected. Farm mechanisation seems to have become, to a certain extent, the neglected waif of agricultural and rural development. As an essential input, mechanisation can transform farm family economies by facilitating increased output and reducing the drudgery of hand-powered production. Mechanisation, when carefully selected and appropriate to the task, is also capable of protecting the environment whilst boosting food production. However, the pace and rate of growth in terms of mechanizing agriculture in SSA, including Tanzania has been relatively slow compared with other parts of the world (FAO, 2013).

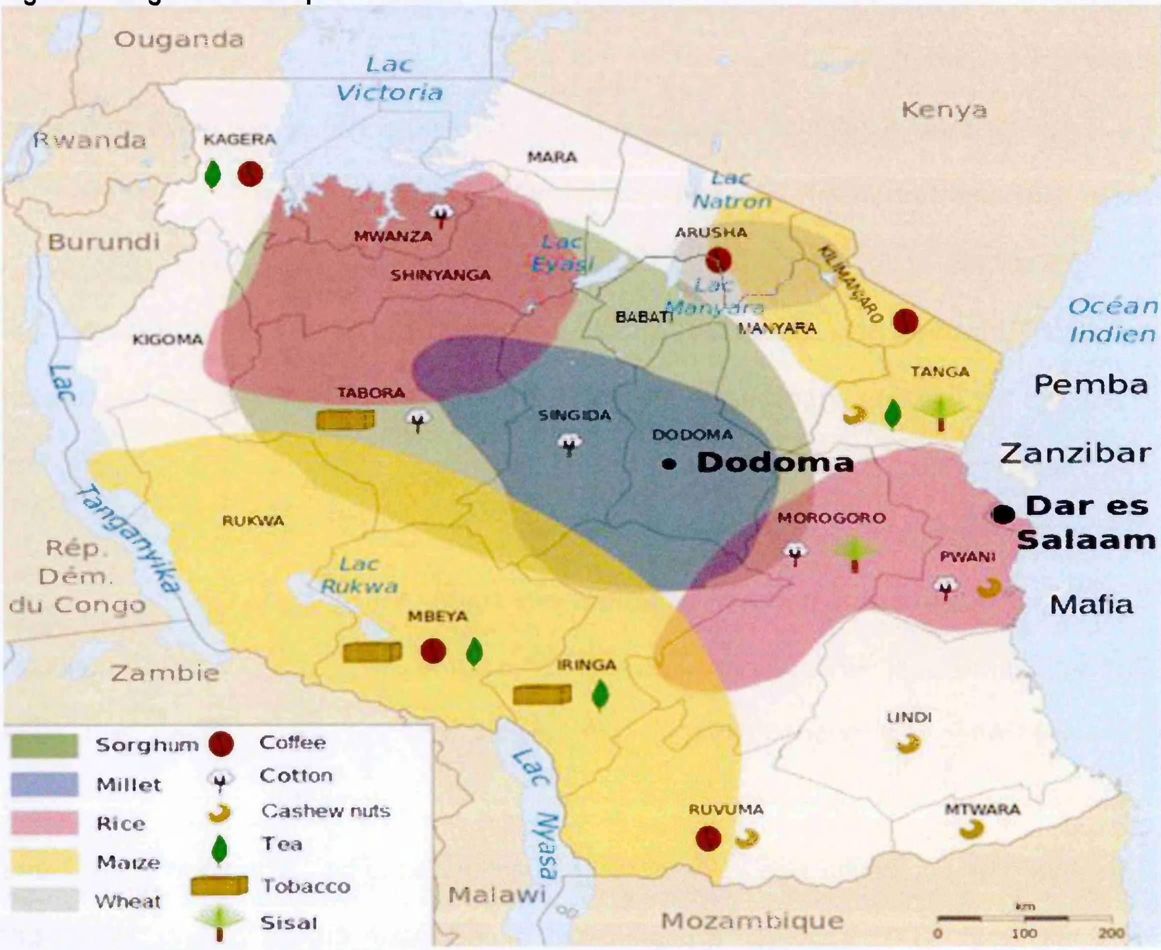
To understand the position of Tanzania in terms of the potential to mechanise agriculture for enhancement of growth in output, employment generation and skill development, an overview of the economic structure will be helpful. This Chapter therefore provides a profile of Tanzania's political economy, and as far as welfare of the citizens is concerned, discusses the role that agriculture is playing, the challenges being faced and the support that mechanisation can give in a changing landscape of world tractor supply and demand.

2.2 Economic situation, national accounts and trade

Tanzania is an East African coastal country, officially known as the United Republic of Tanzania. After the independence of Tanganyika and Zanzibar in 1961 and 1963 respectively, the two sovereign states came together to form the United Republic of Tanzania. The population size of Tanzania was estimated to be 12.3 million in 1967 and 44.9 million in 2012. In 2012, Tanzania had a population growth rate of 1.83% per annum (NBS, 2013). At the time of this study, the country was made up of 21 administrative regions with its commercial capital being Dar es Salaam and Dodoma the administrative capital. See Figure 2.1 for an agricultural map of Tanzania, showing the regions and the major crops grown.

GDP growth of Tanzania outperformed those of its neighbours (Uganda and Kenya) between 2003 and 2012. Compared with developed economies such as EU27, Japan and US averages, growth in Tanzania has also been high. Other developing countries such as India and China had higher or comparable growth rates with Tanzania between 2003 and 2012 (See Table 2.1). Nevertheless, because of the ever growing population in Tanzania, its GDP per capita has not seen significant growth. GDP per capita needs to rise if societal welfare improvement is to gain momentum.

Figure 2.1: Agricultural map of Tanzania



Source: ***http://commons.wikimedia.org/wiki/Atlas_of_Tanzania***

Whilst the income per capita in a developed economy like Japan was about 80 times higher than that of Tanzania between 2008 and 2012, that of an emerging economy like China is about 9 times higher. However, per capita incomes in China were only about 5 times higher than those in Tanzania between 2003 and 2007. This signifies that the high growth rate observed in Tanzania is not keeping up with other developing economies high population growth rates. Thus a change in the nature of growth will be essential to ensure adequate distribution of the gains.

Table 2.1: GDP Growth and GDP per capita by country and groups, 1990-2010

Country and country groups	GDP growth rate (%)		GDP per capita (USD in constant 2000 prices)	
	2003-2007	2008-2012	2003-2007	2008-2012
EU27	2.6	-0.2	31,593	38,055
Japan	1.9	-0.1	34,822	42,685
USA	2.9	0.8	44,087	49,073
China	11	8.7	1,843	4,626
India	9	7.1	770	1,042
Tanzania	7.2	6.7	378	534
Uganda	7.8	6.4	314	472
Kenya	5.4	5.2	551	816

Source: World Development Indicators, 2012

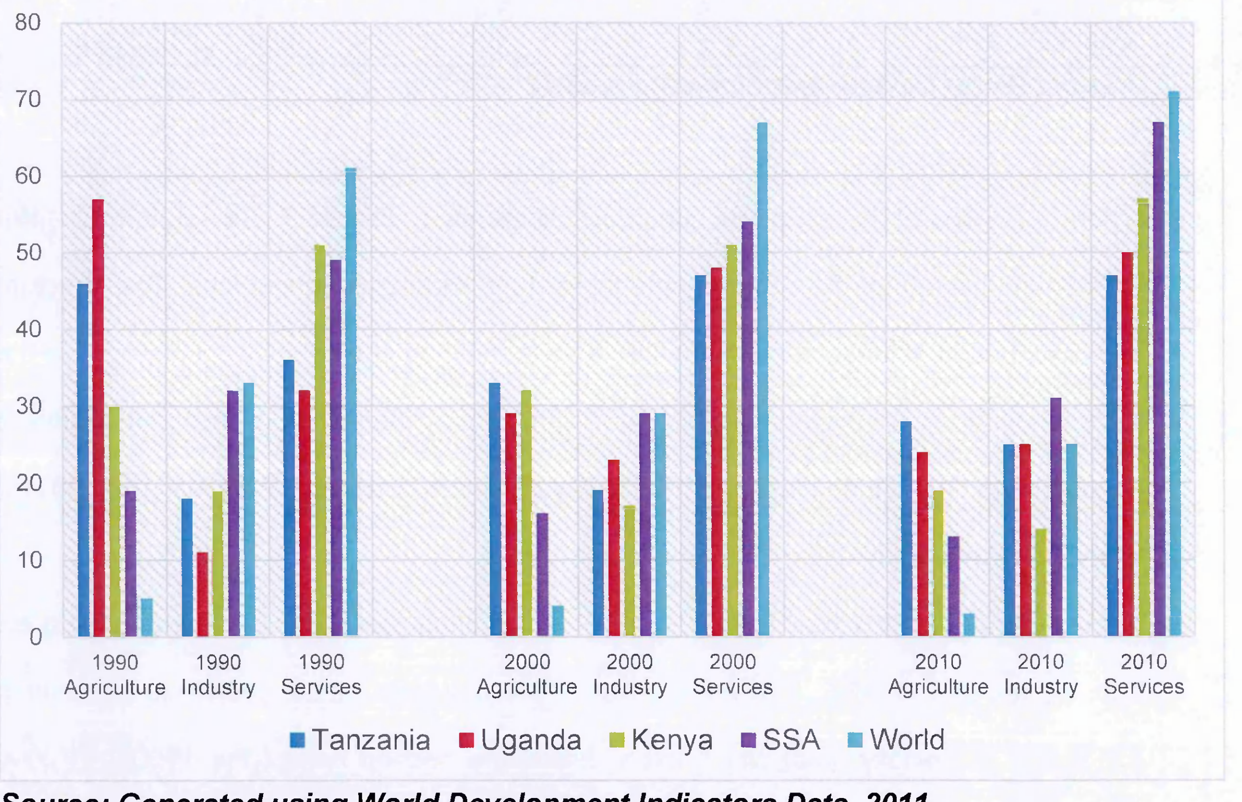
Different sectors of the economy contribute differently to the GDP. As noted in Chapter 1, the main sectors of the economy are agriculture, industry and services. The structure and contribution of these sectors to GDP in Tanzania has seen significant changes in the last two decades. In the early 1990s, at the height of liberalization, the contribution of agriculture to GDP stood close to 50%. Today the value of agriculture is less than 30% in total GDP (See Figure 2.2)

The industrial sector's contribution to GDP in Tanzania between 1990 and 2010 grew from below 19% to 25%. The main driver of the industrial sector growth is the mining sub-sector (especially gold) which expanded in the second half of the 1990s. In 2010 services contributed 50% to the GDP. The growth in the services sector was no surprise, since economies around the world in general are becoming service-based and Tanzania is no exception. However, the changing landscape from agriculture-based economy to services has happened at a slower pace for Tanzania when compared with the rest of the world.

Despite the fact that the agricultural sector's contribution to GDP in Tanzania is shrinking, it is still higher than other countries in East Africa, SSA and the world as a whole (See Figure 2.2). The expectation is that as a sector's contribution to the GDP shrinks, labour employed by the sector would also decline. As demonstrated by the

Lewis two-sector model, labour will migrate into the more productive sectors from less productive sectors where surpluses exist (Lewis, 1954). This has not happened in Tanzania. The shrinking incomes in agriculture are still shared by a majority of the population (Mkenda et al., 2009). In the following Sub-sections, we shall look at each of the three sub-sectors in turn.

Figure 2.2: Sector contribution to GDP by country and country groups (%)



Source: Generated using World Development Indicators Data, 2011

a. Agricultural sector

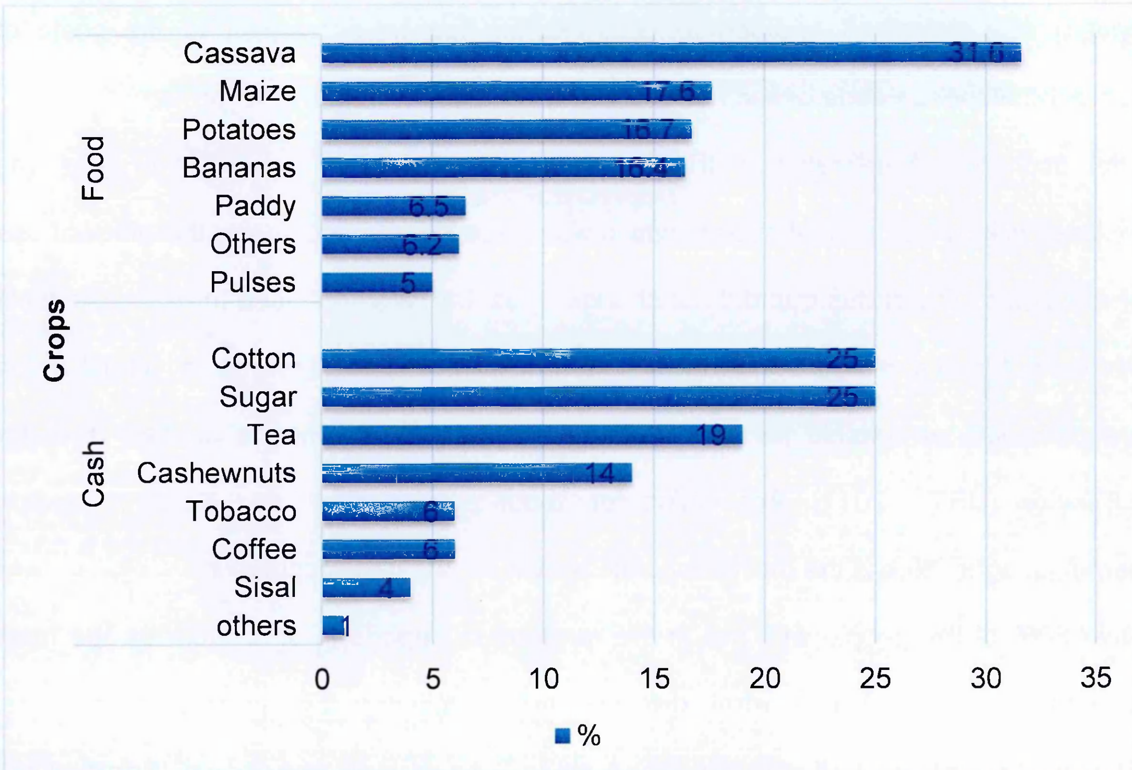
Tanzania's economy is predominately agro-based characterized by low technology peasants engaged in shifting cultivation. The only exceptions are some large scale sisal, sugar cane, coffee and tea farms (Carr, 1985). In Tanzania, the colonial agricultural structure where peasants gradually become commodity producers or labour working on an existing plantation did not change much until 1967. The Arusha Declaration signed by the first president Julius Nyerere in 1967 was supposed to reorganise the structure of agriculture. The declaration emphasised a village system with a series of individual plots worked by households and a bloc farm worked collectively by the whole village. The system also promoted appropriate technologies that were relevant to the scale of operation of these village based farms and the skills possessed by the farmers.

After economic liberalization in the late 1980s, the collective ownership of land was replaced with a free market system which was hoped would encourage the efficient use of resources. The status quo did not change: most farmers continued to use basic tools that did not lead to increased productivity. With a land area of 94 million ha, 44 million ha are classified as suitable for agriculture and about 10.1 million ha or 23% is under cultivation (URT, 2011). Accounting for about 26% of GDP and 33.9% of export earnings, agriculture is the main economic activity for the rural populations.

Over 80% of the people who live in the rural areas engage in agriculture as the main economic activity. These rural dwellers are dominated by smallholder farmers. Smallholder farmers cultivate less than1 ha to 3 ha of land per annum (Sarris et al., 2006). Consequently, the agricultural landscape in Tanzania is dominated by the use of hand hoes, and to a lesser extent by oxen ploughs and mechanical power. Today, based on the type of major implements used, three classes of farmers exist in Tanzania: Mechanized (16%); Animal Power (22%); Hoe and Cutlass (64%), (Lyimo, 2011). Agriculture is also mainly rain-fed. Only 3 to 4% of cultivated lands are irrigated and thus of the 29 million ha of irrigable land, a mere 0.45 million is being utilized for irrigation.

As at 2011 when agriculture employed 75% of the over 20 million labour force, the crops sub-sector made up 72% of the entire sector. Of those employed in the agricultural sector 56% were women cultivating mainly food staples. The main staple crops produced and consumed in Tanzania are roots and tubers and cereals. Predominant among these are cassava, maize and potatoes. Between 1998 and 2008, over a third of all crop output in the country was cassava. This was followed by maize, a little under a fifth, and then by potatoes. The main cash crops were cotton, sugar and tea. In volume terms, cotton and sugar cane constitute about half of all cash crops produced (See Figure 2.3).

Figure 2.3: Food and cash crops composition, 1998-2008



Source: Ministry of Food and Agriculture, November 2008

Between 2000 and 2010, yield of major staple crops in Tanzania declined when compared with those of its neighbours, Uganda and Kenya. For example whilst the yield of maize per hectare stood at 1.9 in the year 2000, in 2010 it had declined to 1.6. During the same period, yields in Uganda rose from 1.7 to 2.3 and those in Kenya from 1.4 to 1.7 per ha (See Table 2.2 below). These occurrences cast doubts on the possibility of attaining the objectives of the Tanzanian Agricultural Sector Development Strategy adopted in 2006. The strategy aimed to sustain a 5% growth of the agricultural sector per annum. With current declines in productivity, it is unlikely that such targets will be attained.

Table 2.2: Yield per hectare (maize) by country and selected years

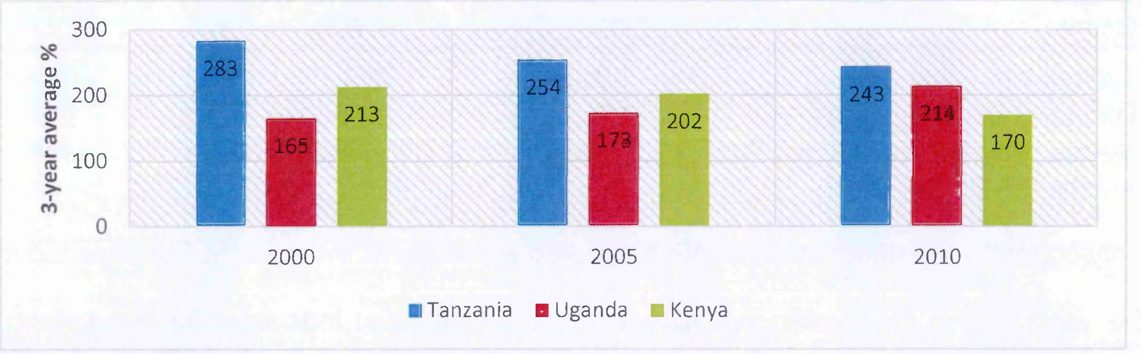
Country	2000	2005	2010
Tanzania	1.9	1.0	1.6
Uganda	1.7	1.6	2.3
Kenya	1.4	1.6	1.7

Source: FAOSTAT

Consequently, the depth of food deficit has also worsened in the country. For instance in the year 2000 a three-year average of the kcal/capita/day indicated that food deficit stood at less than 17%. However in 2010, the figure stood close to 80%, which is a cause for concern. Despite the fact that these levels are much better than its neighbours, there is alarm because the situation is deteriorating. Uganda for instance is making good progress in terms of reducing food deficit levels, whilst Kenya's case is worsening at a relatively slower rate compared to Tanzania.

Food security is a consequence of availability, accessibility and affordability. To make food available farm lands must be productive. And the productivity of farms is influenced by the quality of production inputs. One of such inputs is farm implements: hoes, cutlasses, oxen ploughs, power tillers and tractors. Regardless of the farm size and crops produced, farm implements are required for the production process. Whilst it is possible to obtain the hand hoe/cutlass and oxen plough from local industries in Tanzania, it is practically impossible to do same for power tillers and tractors. Tanzania does not currently have the requisite competence to manufacture power tillers and tractors. As we shall see in the next sub-section the underdeveloped nature of metal fabrication and auto industries in Tanzania means that local production of these machines is currently beyond reach. Thus the country's demand for tractors and power tillers must be met by foreign sources through importation, an important point which underlies this study.

Figure 2.4: Depth of food deficit in East Africa (kcal/capita/day, 3-year average), %



Source: FAOSTAT

b. Industrial and manufacturing sector

Tanzanian industrial policy in the 1960s and 1970s sought to facilitate the production of capital goods. It was hoped then that firms producing such capital goods would adapt them to and support the local manufacturing regimes to meet basic needs of the entire populace. Thus central government invested heavily in the sector at that time in order to kick-start it. These industries were also expected to provide training where necessary and develop new skills where possible. It was however difficult for such manufacturing firms to thrive and deliver the expected gains.

Nonetheless, there are still over 700 manufacturing firms in Tanzania and the number continues to grow. Of these, 6% were into the manufacture of basic metal sheets and fabricated metal products. This statistics shows the extent to which competence and capabilities for the manufacture and maintenance of agricultural capital goods made mainly of iron and steel are lacking in the country. It must however be noted that the growth rate of the manufacturing sector was 8.2% in 2012 (NBS, 2012 Population and Housing Census, Tanzania, 2013). Thus there is evidence that the sector could expand in the future to provide the platforms required to manufacture capital goods locally.

There is also a cautious optimism that the existence of a bus assembly plant in Tanzania could become the starting point in developing other products such as tractors and power tillers. There are numerous car garages scattered across the country but their main clients are not the agricultural machinery users although sometimes they provide support to the sector. These businesses hold the potential for the future growth of local manufacturing of agricultural capital goods. There have also been a few signals that Iran Tractors and M&M may start assembling tractors in the country in the near future. While we wait for the development of the metal work industry to support agricultural capital goods production, there is the need to find and facilitate a reliable supplier abroad, through trade and related services. To facilitate smooth imports from abroad and distribute them across the country, well-functioning financial services, healthy business environment and port infrastructure are key. We discuss these in the next sub-section.

c. Services and the business environment

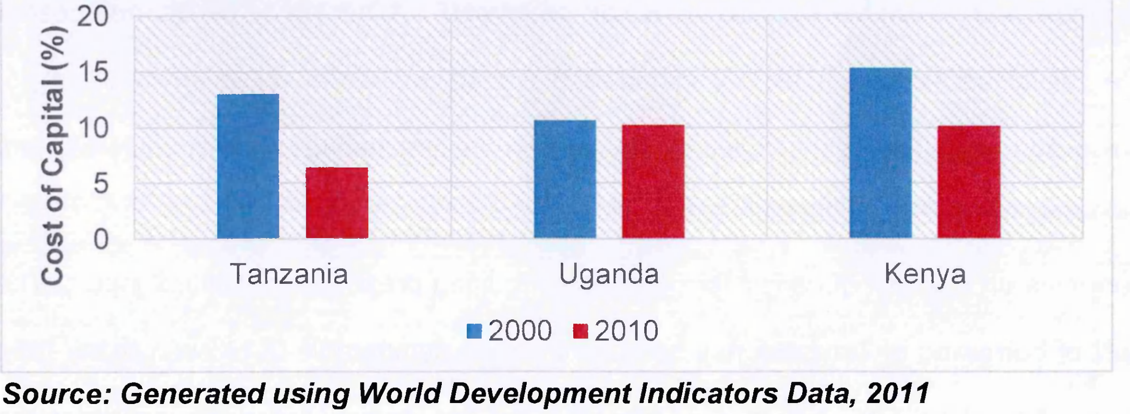
The liberalization of the Tanzanian banking business in the early 1990s and insurance business in the late 1990s attracted several players in the financial services sector, including world class banking institutions such as Barclays, Citibank, Standard Chartered, as well as regional banks such as ABSA and Standard Bank of South Africa. The insurance sector has a number of regional players such as Jubilee, Royal, Lion and Phoenix. In total there are over 30 registered banks and other financial institutions and more than 10 registered insurers operating across the nation. Though micro-insurance schemes are at their infant stages and mainly concentrate on health and life premiums, there are considerations to insure the agricultural sector provided weather forecast infrastructure could be improved and expanded across the county.

The development of the financial sector is important for both importers and users. The swiftness with which bank transactions can be carried out, access to capital and cost of the capital accessed are all key variables that feed into an effective environment for doing business. The cost of capital has fallen in the last decade with real interest rate declining from 13% in 2000 to 6.4% in 2010 (See Figure 2.5). There are also further subsidies on the cost of capital for borrowers requiring credit for agricultural inputs. The cost of borrowing in Tanzania has been on average comparable to or even better than those of its neighbours, Kenya and Uganda in the last decade. However, lending to the informal sector and agriculture in particular by commercial banks remains scanty because of the high risk involved. Only about 12% to 15% of commercial banking credits go to finance the agricultural value chain. Of this proportion, over 90% goes into agricultural marketing chains with a small proportion going to production and input supply (Jessop, et al., 2012).

The key constraints financial institutions face in lending to agriculture include: inherent risks due to unpredictability of weather; lack of collateral due to low market value of land and in some cases lack of land title, un-surveyed land; price volatility of crops; underdeveloped local markets due to poor rural infrastructure (roads, telecommunication) and outdated agricultural technology. In view of these, the banks usually decline to offer long term loans to farmers who usually do not have bank accounts (Seluhinga, 2013).

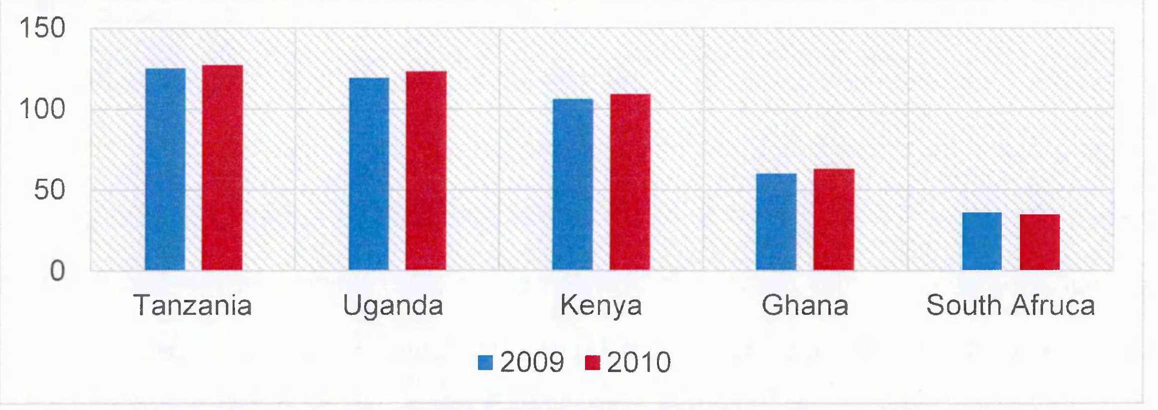
The business environment is also crucial for the importation of agricultural capital goods. This is an area where Tanzania has performed poorly (Figure 2.6). Out of 183 countries, Tanzania ranked 122 and 123 in 2009 and 2010 respectively on the scale of ease of doing business. This position on the ranking is neither better than Kenya nor Uganda. It is much worse when compared with other SSA countries such as Ghana and South Africa's. Improvements are needed to facilitate trade, investment and other economic activities that could assist in smoothing transactions pertaining to tractor imports.

Figure 2.5: Cost of capital (real interest rates) in East Africa, 2000 and 2010 (%)



Source: Generated using World Development Indicators Data, 2011

Figure 2.6: Ease of doing business in Tanzania compared with other countries



Source: Generated using World Development Indicators Data, 2011

2.2.1 Institutions and infrastructure in Tanzania

Government and Non-Government institutions as well as physical infrastructure are important fundamentals for technology transfer, diffusion and adoption. They define the ease with which business can be undertaken. This sub-section looks at how institutions and infrastructure in Tanzania impact on the innovation systems of farm mechanisation.

a. Government

Despite liberalization of many sectors of the economy, central government presence in the day to day activities of businesses in Tanzania is pervasive. This is because government still has shares in a number of parastatal companies. In the agricultural sector, the importance of government is felt through the Ministry of Agriculture, Food Security and Cooperatives (MAFC). As part of its vision of modernising agriculture through the Kilimo Kwanza policy embarked upon in 2009, the Ministry has targeted the development, promotion and use of appropriate agricultural technologies. The objective is to modernise and commercialise agriculture for peasant, small, medium and large scale producers (Rutta, 2012). To this end, the Ministry collaborates with the private sector, local government and other service providers to make relevant technical inputs into research, extension, irrigation, plant protection, land use, mechanisation, agricultural inputs importation, information services and cooperative development.

For instance, to deal with financial challenges being faced by the agricultural sector, there are attempts by government to transform the Tanzanian Investment Bank into an Agricultural Development Bank. The objective is to create a bank that will serve as a lending agent for government and other international lending institutions that target the needs of farmers. To remove some of the capital constraints, the Bank will train, provide consultancy services and monitoring of activities of other lenders in the sector. Apart from these, the Agricultural Input Trust Fund established in 1994 provides wholesale lending for the procurement of inputs and equipment (tractors and power tillers). The trust also subsidises land titling procedures for prospective borrowers. Beneficiaries of such subsidies can use their title for other transactions even if the requested credit from the trust does not go through. It must be noted however that for a farmer to source many of these assistance, he/she must be a member of a recognised association. (Key informant interview with the Director of the Fund, 2012).

b. Cooperatives and NGOs

Tanzania has been home to many marketing cooperatives composed mainly of peasants without titled estates, producing mainly coffee and cotton for export. Cooperatives are so important in Tanzania that it has a department under the agricultural ministry. Between 1930 and 1960, they were very vibrant in the purchasing of pesticides and seeds in bulk from manufacturers and distributing them to their members. Some of the unions were also known to have bought and loaned tractors to their members. In a rather rare instance, one big cooperative built and operated a warehouse for the sale and servicing of tractors for members to access in the Mwanza region and became very useful to farmers in the 1960s. The cooperatives were also instrumental in export trade (Maghimbi, 1990; Maghimbi, 2010).

Cooperatives increased rapidly in number with firm support from government and a motivation to help peasants keep a greater proportion of their sales profit. Aside from marketing cooperatives, there were also consumer, credit and transport cooperatives with diverse objectives. Indeed the marketing cooperatives in the cotton industry provided the initial drive for the establishment of ginneries in the cotton growing areas. Allegations about cooperative managers of being corrupt after independence led to a government enquiry, which eventually led to their dissolution and their marketing powers devolved to village leaders.

The cooperatives resurfaced in the 1980s but they have not performed as well as before, especially the crop marketing ones (Maghimbi, 2006). Their fund-raising ability for the purchase of crops of members has declined from over 35% to about 0.75% of the value of sale by members. Though the savings and credit cooperatives were not so vibrant in the 1960s, they currently form about 50% of all cooperatives and had over 1.6 million members in 2008. The vibrant nature of cooperatives in Tanzania gives them a voice in lobbying government agencies and other support institutions such as finance and trade. These activities put the cooperatives in a position to give voice to the farmers in terms of discussions pertaining to sourcing inputs, pricing and terms of supply; a tool that could be useful for the importation of appropriate tractors and power tillers.

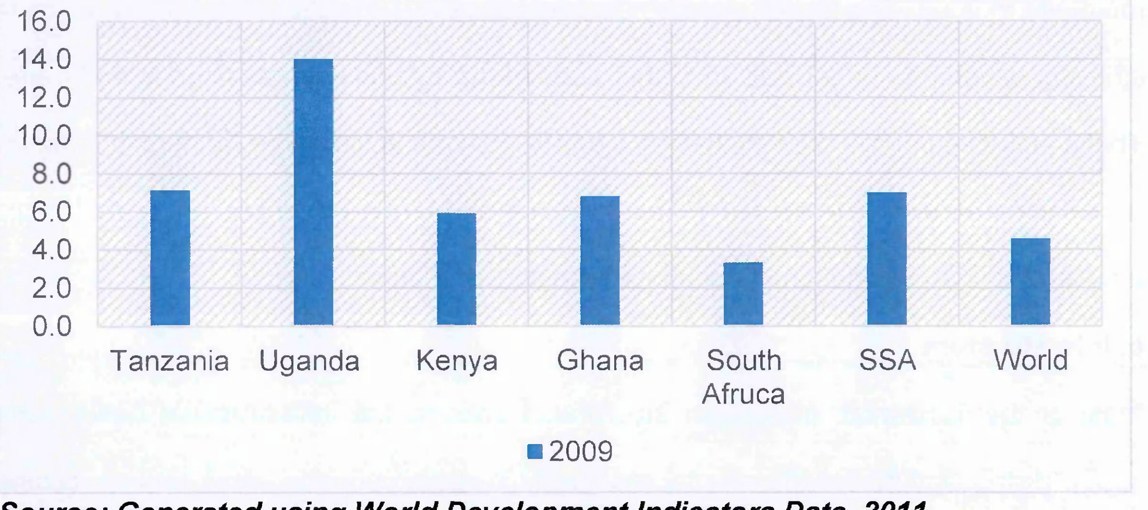
c. Infrastructure

Most of the Tanzanian population are rural. However, the infrastructural design and spatial distribution across the country are mainly in and around the urban centres, cutting most rural dwellers from all year round roads and electricity supply. Though electricity is relatively cheap in Tanzania compared to Kenya and Uganda, less than 20% of the Tanzanian population have access to electricity. Most rural roads are unpaved. Nevertheless, there is an extensive connectivity of urban centres by trunk roads and neighbouring countries via rail. Despite privatization of 51% stakes in the rail infrastructure, to an Indian investor in Tanzania, expected gains are yet to be seen (AICD, 2010). The rail network also links the Dar es Salaam port to the interior of the country and facilitates the haulage of imported goods and goods going to be exported. The frequency of rail services are however very low and sometimes unreliable.

Closely linked with the rail and road infrastructure is Dar es Salaam port. The Dar es Salaam port handles about 200,000 containers and 3.8million tons of cargo annually.

This is half of the operations of Mombasa, the Kenyan counterpart. Compared with other SSA countries, it is an efficient port. There is a low container dwell time of 6.8 days which is not significantly different from the SSA average. It is however much better than Uganda (14 days), probably because of its landlocked nature but greater than Kenya's (6 days) which has a long standing reputation of a busy port (See Figure 2.7). There is also low truck processing time of 5 hours and a productivity of 20 containers per crane hour. The port is however yet to fully apply the Landlord Port System[1] which has been found to be more efficient in the experience of other countries.

Figure 2.7: Lead time to clear imported goods from the Dar es Salaam Port (days)



Source: Generated using World Development Indicators Data, 2011

Communication is also important for any business transaction. It is even more crucial for farmers since their main place of work is usually far away from input suppliers. Soft infrastructure, especially mobile phone technology has removed many of the communication barriers for the rural population as a result of its liberalization in the early 2000s. Thus rural farmers are able to engage with input suppliers, repairers and operators via the mobile phone. Today, the mobile phone system is used as a money transfer platform in Tanzania. This has the potential of transforming payment systems

[1] The landlord port system is characterized by its mixed public-private orientation. Under this model, the port authority acts as regulatory body and as landlord, while port operations (especially cargo handling) are carried out by private companies.

especially for farm tools, spare parts and other inputs. Mobile phone penetration currently stands at 56 units per every 100 persons compared with 44 and 71 for Uganda and Kenya respectively in 2013. However, as it is common in SSA to share mobile phones or to use public mobile phones, mobile services extend far beyond actual penetration levels (World Bank, 2013).

Other on-farm infrastructure such as irrigation is also important. This is so because, to realise the full benefits of investments in power tillers and tractors, reliable water supply cannot be taken for granted. Irrigation potential in Tanzania is great because of the abundance of lakes across the country. This potential is however yet to be harnessed. Irrigated lands (184,000 ha) is about 9% of irrigable land. (URT, 2011).The prevalence of a uni-modal rainfall pattern in some parts of the country requires irrigation infrastructure investments to ensure maximum use of land resources. The expensive nature of irrigation equipment and infrastructure has made such ventures prohibitive.

2.2.2 Labour force capabilities, core competence and employment

Beyond well-functioning institutions and reliable physical infrastructure, a well-trained labour force is required to man and maintain mechanised capital goods if the sector is to serve as an employment creation mechanism. Unemployment rate for all classes of labour force in Tanzania decreased slightly from 12.9% in 2001 to 11% in 2006 (NBS, 2007). However according to the National Integrated Labour Force Survey, over the same period youth unemployment increased from 13.6% to 14.9%. Econometric estimations using the integrated labour force survey data for Tanzania suggests that among other things, education and skill training are important drivers of the rise in youth unemployment in the country (Msigwa & Kipesha, 2013). There are skill gaps which need to be addressed if youth unemployment is to be curtailed.

Formal academic education in Tanzania has traditionally been preferred to vocational and technical training. After independence, government policy focused on a self-reliant strategy that targeted every stage of education as a useful tool for community development. For this reason, primary education was supposed to go hand-in-hand with vocational and agricultural technology training. However parents and teachers felt that there was better paying jobs in urban centres and the only way for their children to get them was to concentrate on formal training and not the rudimentary knowledge in agriculture and craftsmanship. Despite these setbacks, the remnants of such legislation in the late 1970s and 1980s continue to give students the opportunity to enter vocational and technical colleges at different points along the educational path.

In Tanzania the two most common paths are to enter vocational school after primary or to enter technical colleges after O-level. Both public and private institutions provide vocational and technical training. There are over 250 post primary technical centres scattered around the country with the objective of equipping primary school leavers with training in carpentry, brick laying/masonry, blacksmithing, auto mechanic and other trades. The Technical Schools (about ten of them in total) specialize in training students in workshop technology associated with Electrical, Civil and Mechanical Engineering (motor vehicle mechanics).

The main weakness of these otherwise useful institutions is that in the past it has not offered courses pertaining to entrepreneurship and financial literacy that will help the students manage their skills when they graduate. There have also been situations where teaching staff and equipment have been inadequate (Mbelle, 2008). Some companies also give on-the-job training. There are also NGOs and religious groups which support and operate technical training centres. Youth apprenticeship under artisans and tradesmen after standard VII also exists. This form of training is informal but very useful in providing skills for school leavers. After completion of such training young 'gradates' are free to set up their own business. However, for them to gain formal employment there is the need to pass the trades' test which is nationally recognized for artisans. These kinds of artisans, especially auto mechanics, have been found indispensable on medium and large scale farms where mechanized equipment such as tractors are used and need regular maintenance (Bennell, 1999).

At the formal front, as per the results of the Tanzanian Household Budget Survey 2008, the literacy rate among 15-24 year olds (youth literacy rate) is 80.0%. On average 83.0% of males and 76.9% of females are literate, and this compares well with the World and SSA averages of 89.3% (male: 91.9; female: 86.8) and 74.3% (male: 79.0; female: 69.9) respectively (URT, 2011). While literacy rates may be an important measure, the skills and technical capabilities of the labour force have a more direct bearing on the agricultural mechanisation value chain and how well it is managed. Managers who understand how the world trade order works are required to import and distribute the machines; entrepreneurs who can run the tractor business profitably are also needed to buy, use/hire out machines at the farm level, and operators and repairers are also needed to keep the machines running. Building such core competence and capability through learning by doing should engage the educational system if rapid transformation of the labour market in Tanzania is to be realized.

2.2.3 Diplomatic relations and international trade

Trade and diplomatic relations, as well as migration are ways through which countries engage. Through such engagements, there is cultural exchange. Beyond culture, some of these engagements also facilitate the transfer of knowledge, skills and technology. Tanzania's pre-colonial, colonial and contemporary history suggests that it has engaged with different people from different countries across the globe. This is demonstrated through the diversity of people across the world who have made Tanzania their home (Rweyemamu, 1973). This Section touches briefly on Tanzania's engagement with some Matured Market Economy countries and Emerging Economies. Specifically, we emphasise the countries which matter when it comes to Tanzania's international trade and which are also important as a source of tillage technologies for the country.

a. International relations

The **EU, Japan** and **USA** are the three main advanced country groups which are important in the Tanzanian tractor markets. On the other hand, **China** and **India** are the two main emerging economies which have strong diplomatic and trade relations with Tanzania. We discuss these countries and their diplomatic relations with Tanzania in turn with the view of briefly understanding how such relations could affect tractor imports.

European Union and others

Tanzania began the 20th century as a colony of **Germany**, and ended up in the hands of the British after the First World War (WWI). Tanzania thus had strong ties with the British through trade, exporting mainly primary agricultural products to Britain. Tanzania's decision to support the liberation of other Southern African states meant that its diplomatic relations with Britain were severed in the early 1960s, after independence. Though diplomatic relations were restored in 1968, it was not until 1974 when Britain decided to restore aid and support to the country again. Since then, the nature of trade between the two countries has not changed significantly: Tanzania exports primary commodities to Britain and imports manufactured goods. Similar trade relations exist between Tanzania and other European nations. In terms of the tractor trade the UK, Italy, Finland, Russia and Poland were very important for Tanzania between the 1960s and 1990s.

USA

The **USA** Government provides assistance to Tanzania to support programs in the areas of health, environment, democracy, and development of the private sector. The U.S. Agency for International Development's program in Tanzania averages about $20 million per year. Trade ties between the USA and Tanzania are however on the low side when compared with other developed countries. Nevertheless, US tractor brands like John Deer and CASE IH are very popular on large scale commercial farms in Tanzania.

Japan

Japan recognized Tanganyika immediately after its independence from the United Kingdom in December 1961. Zanzibar became independent in 1963 and Tanzania was founded in April 1964 when Tanganyika and Zanzibar formed a union. Since then, Japan has enjoyed friendly and cordial relations with Tanzania. Throughout the history of friendship between Tanzania and Japan, there have been numerous important visits in both ways by diplomats.

Japan started to assist Tanzania in its endeavour to develop the country as early as 1966, when Japan extended its first concessional credit to Tanzania. In 1967 the first young volunteers were sent to Tanzania and they mixed with ordinary citizens, and farmers to teach their children in schools, help patients in hospitals and work together in local governments. Now the accumulated number of young volunteers exceeds one thousand. Specific to agriculture, Japan built the Kilimanjaro Agricultural Training Centre for Tanzania in the 1980s and has made several donations of tractors and power tillers through JICA (Key Informant Interview with the Director of the Centre, 2012).

China

China established diplomatic relations with Tanzania in the early 1960s when Tanganyika and Zanzibar (two independent states) joined to form the United Republic of Tanzania. The bilateral relations are extensive and encompass political, economic, military and cultural cooperation (Jansson, Burke, & Hon, 2009). Because of the location of Tanzania in the East African coast, it is an important country as a point of entry for China's trade with southern African states (Alden & Alves, 2008).

The government of Tanzania's long standing relationship and a reputation as an early aid recipient from China has created a very fluid diplomatic link at the state level between the two countries. From major constructions such as a railway line between Tanzania and neighbouring countries in the 1960s, irrigation infrastructure at the Mbarali rice estates in the 1970s, textile manufacturing plant in the Dar es Salaam in the 1970s, China continues to support Tanzania through aid. China also regularly sends medical teams from one of its provinces to provide support in the health sector.

In 2006 China pledged to build an agricultural demonstration centre in the Morogoro region to enhance agricultural technology transfer to farmers in the country (Brautigam, 2009) . The construction is under way at a site near *Dakawa.* In addition to its embassy in China which gives information to prospective Chinese investors in Tanzania and vice versa they also established a Business Chamber in 1997 (Jansson, Burke, & Hon, 2009). This centre has the motive of establishing links between producers of consumer and capital goods in China and other players involved in the value chain responsible for the import and export process. The two countries have also signed a number of economic, trade, aid and technical cooperation agreement (Moshi & Mtui, 2008).

India

Shared ideologies in anti-colonialism, anti-racism, socialism and desire for cooperation among southern states drove the political relationship between Tanzania and India from the 1960s to the 1980s. In 1961 India opened its high commission in Dar es Salaam. The large presence of people of Indian nationals in Tanzania has also driven the business and commercial relations between the two countries. India has become an important source of machinery and pharmaceutical products for Tanzania. There is also a large presence of Indian companies in the financial, minerals and trading sectors of the economy. Some of them are also involved in the Agricultural sector, mainly producing cash crops and certified seeds.

Aside from two cashew nut processing plants donated by the Indian government to Tanzania in 2012, they have also established a centre of excellence in ICT and another project in the University of Dar es Salaam aimed at providing up-to-date IT education. In 2010, India extended a line of credit of $50 million to Tanzania for financing the agricultural sector. Tanzania has since used the money for the importation of tractors from India.

b. Trade

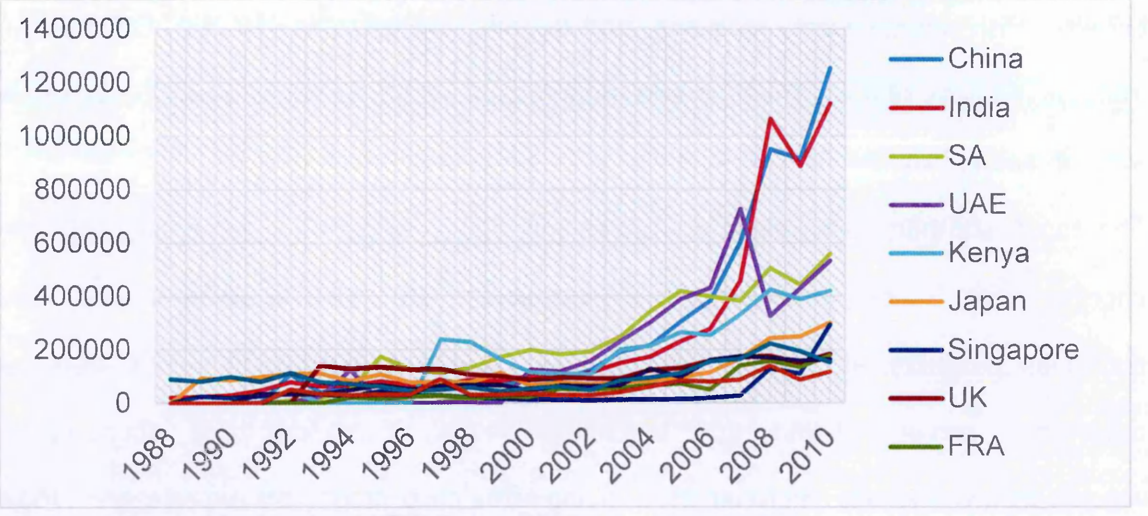
Aside from the political relationships reflected through aid and various forms of agreements, trade has also played a strong role in shaping the relationship between Tanzania her partners. In 2010, whilst merchandise exports from Tanzania to the rest of the world totalled over $3 billion its merchandise imports totalled over $7 billion. In 2008, commercial services exports totalled over $1.9 billion while commercial services imports totalled over $1.6 billion. The top five export categories for Tanzania in 2010, along with the percentage of total exports, were: Pearls, precious stones, metals, coins, etc. (12.4%), Fish, crustaceans, molluscs, and aquatic invertebrates (10.2%), Coffee, tea, mate, and spices (8.4%), Tobacco and manufactured tobacco substitutes (7.3%), Ores, slag, and ash (7%).

The top five import categories for Tanzania in 2010, along with percentage of total imports, were: Boilers, machinery, nuclear reactors, etc. (12.6%), Mineral fuels, oils, distillation products, etc. (12%), Electrical and electronic equipment (10%), Vehicles other than railway (9.4%), Iron and steel (4.2%). The top three countries to which Tanzania exports merchandise, along with percentage of exports, are: India (8.1%), Japan (6.5%), and China (6.3%). The top three countries which export merchandise to Tanzania, along with percentage of imports, are: China (14.4%), India (9%), and South Africa (7.7%)[2]. See Figure 2.8 and Figure 2.9 for the Tanzanian trade partners and the import and export values to and from these countries.

The graphs in Figure 2.8 and Figure 2.9 show that Tanzanian imports from and exports to all the top eight countries begun to rise quickly in 2003, probably as a result of the significant growth rate witnessed within the economy in the previous years. Worthy of note is how much more quickly the imports and exports related to China and India fared during the same period. There were significantly higher levels of commodity trade between Tanzania and China/India between 2007 and 2010, while their engagement with other economies grew at a slower pace.

[2] *Sources: World Trade Organization, International Trade Centre, and World Factbook*

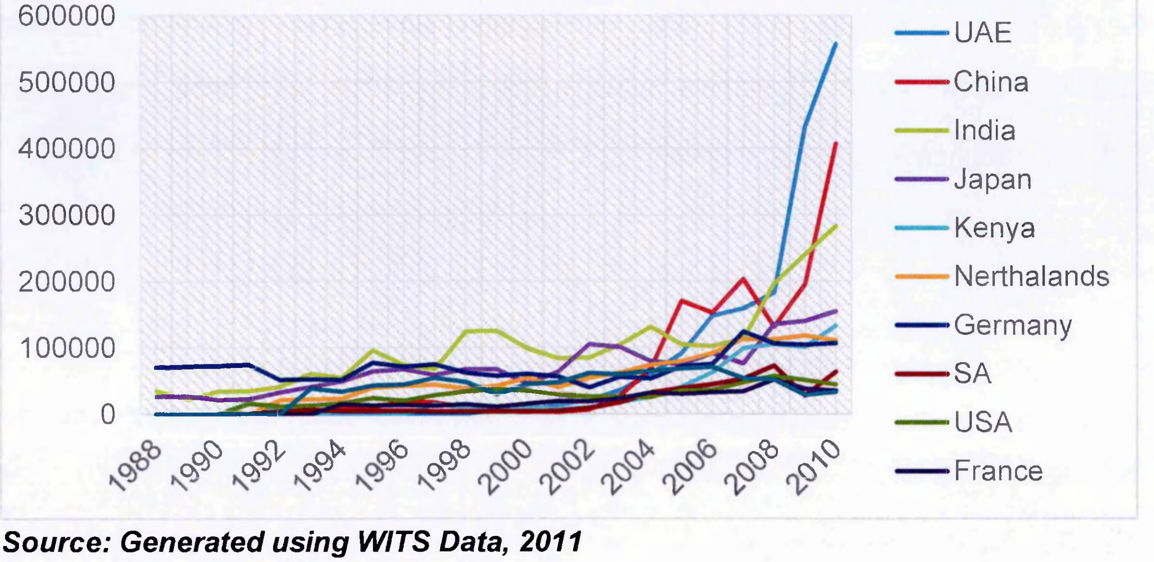
Figure 2.8: Imports, source and value ('000 of current US$, 1988-2010)



Source: Generated using WITS Data, 2012

These growing trade ties between Tanzania and China/India can equally serve as a platform for importing agricultural capital goods, a subject matter of this study. In the next Section therefore, we discuss the Tanzanian and international tractor and power tiller markets and how the presence of China and India in the global trade is creating a new platform through which Tanzania can source capital goods.

Figure 2.9: Exports destination and total Value ('000 of current US$, 1988 to 2010)



Source: Generated using WITS Data, 2011

2.3 Agricultural mechanisation in Tanzania: how far so far?

Over the past fifty years, policy makers in Tanzania have recognised the importance of mechanizing agriculture. For instance in the defining moment of appropriate technology debate in the 1960s and 1970s, Tanzania played an important role. The first President of the country, Julius Nyerere, half a decade into independence, declared that it was incorrect for the country to depend on the North for their progress in terms of technology and policy. He and his contemporaries argued that there should be efforts to develop or select from intermediate technologies. To this end, the country's agricultural sector received some attention in terms of investment in intermediate tillage technologies such as animal drawn implements and simple irrigation wells (Rweyemamu 1973; Carr, 1985). The status quo has however not changed significantly in the last five decades: the hand hoe is still a predominant tool on the farm.

Some of its policies of the Arusha Declaration left some good legacies for agriculture, including well defined land rights vested in the hands of village committees. However saturation of the sector with rudimentary tools made production beyond subsistence difficult. Labour capability and skills were also generally conditioned by these simple farm tools. In addition agriculture was mostly rain-fed and periodically affected by droughts, resulting in low productivity (Sarris, et al., 2006; NBS 2010). Economic difficulties encountered by the country's economy in the 1980s reduced the attention that Tanzanian policy makers gave to appropriate technologies. Policy shifted toward liberalization and structural adjustment. Casual empiricism suggests that despite the policy shift, the agricultural landscape has not changed much and the sector is still dominated by smallholder farmers producing mainly for subsistence.

The level of mechanisation is low with the hand hoe dominating in farming systems (Mashindano et al., 2011). In 2006, 68% of all farms in the country used the hand hoe as the main tool for tillage. In the same year, the proportion of farms using animal power and mechanical power stood at 22% and 10% respectively (Menenwa & Maliti, 2010). In

2010, there was a decline in hand hoe use to 64%. In the same year, the use of animal power reduced to 20% while mechanical power usage rose to 16% (URT, 2012).

Attempts to commercialize agriculture among small and medium scale farmers in the country as proposed by the Agricultural Sector Development Strategy of Tanzania, 2001, require the selection and use of appropriate mechanisation equipment. A strategy targeting a gradual increase in the use of low cost intermediate technologies such as power tillers and small tractors which are easy to handle by farmers and the prevailing infrastructure could be a viable option. Moving on to more complex technologies that may be expensive and capital intensive will demand improvement in incomes, infrastructure and support services: a maze of activities and physical assets which the country does not currently possess.

Miniature tractors (power tillers) are a much more likely improvement over the oxen plough which some farmers are already used to. Therefore a transition into their use may present lower skill barriers for the farmer. However, as per differences in soil characteristics across the country, not all geographical locations will find such small tractors and power tillers useful- iron pan soil concretions may require heavy duty tractors to carry out tillage activities. Thus one cannot also totally rule out the use and need for large tractors. Therefore with the revamping of the mechanisation drive in Tanzania in the 2000s, the watch-word should be appropriateness of the technologies selected from the existing range on the market. Attention should be paid to the different classes of farmers in the country and their particular needs. Presently, Tanzania does not produce power tillers and tractors; there is very little evidence to show that this is going to change soon. Therefore choice of mechanisation technique in Tanzania derives from a global value chain dominated by European, American and Asian manufacturers.

We are in a disruptive stage in the world economy. The centre of world manufacturing is shifting to emerging economies like China and India. Similar observations have been made in the tractor industry. In the last decade, the significance of China and India has grown tremendously when it comes to the manufacture and use of tractors and power tillers. Since China and India have incomes, farm sizes and cultural characteristics that differ from the advanced countries, it is likely that the tractors and power tillers they produce will differ in character. The international market for power tillers and tractors is changing and so the range of technologies available for the Tanzanian farmer to make a choice is also widening. To understand the dynamics of the tractor market and the extent to which the characteristics of the machines produced reflects endowments of the societies which produce them, the sub-sections which follow discusses the structure of the global market of tractors and power tillers.

2.3.1 Brief history of tractors and power tillers in the last century

The introduction and use of tractors on farms around the globe is eleven decades old. Starting with USA and Western European agriculture, the use of tractors began around 1902. Based on steam engine designs developed in the 1800s by Scottish engineers, further innovations generated gasoline engines in the early 1900s (Hodge, 1973). The steam powered engines were first used in Britain. However the heavy and wet nature of soils in England meant that a pair of oxen was more economically efficient than the steam ploughs. In the USA where soil conditions were suitable, steam powered ploughs were used well into the 20th century until reliable internal combustion engines were developed.

Meanwhile, attempts to build and commercially sell petrol powered engines in the 1890s in the US failed. However, between 1901 and 1902, British engineers produced and sold the diesel engine. The major participating companies in these developments were located in the USA and in Western Europe. Major break-through in the automobile industry by the Ford company were relied upon to modify tractor designs to make them simpler, relatively lower cost and more accessible to farmers in the 1910s and 1920s. By the late 1910s companies in Italy and Germany developed their own brands and this pushed the technology further. Spreading to other Eastern European countries like Ukraine and Belarus in the USSR, the use of tractors become widespread in the 1930s.

In the 1950s, the technology spread to other parts of the world. India and China joined in the production of these machines around the 1950s through collaboration with well-established companies in the West. Though Japan had joined in the process earlier, it was not until the 1960s when their brands which were typically small in nature but very robust become popular.

Tractor use on farms has become ubiquitous in the developed world. It is however uncommon on farms in developing countries in SSA. In Africa and in Tanzania in particular, tractors were introduced by European settlers in the 1950s who worked on cash crop farms (Kjaerby, 1986). After independence Tanzania showed strong commitments to modernize its agriculture and so invested state resources to develop access to tractors by farmers. Economic challenges in the early 1970s and 1980s curtailed such interests. Economic recovery in the 1990s and 2000s has triggered new interests in tractorisation (Hatibu, 2013). Thus in 2009, the government launched the *Kilimo Kwanza*[3] scheme which among other things sought to revamp mechanisation in the country (Mmari & Mpanduji, 2014).

Similar to the evolution of tractors, the first design and appearance of power tillers on the market were started by Swiss manufacturers in 1910 and filtered through other parts of Europe particularly Germany and Italy but also the USA in the 1910s. After the WWI, a returning Japanese combatant who had seen the Swiss design being demonstrated in a nearby village by his government made his own version of the power tiller in 1926. His initiative was triggered when the agent who imported the Swiss machines stopped in 1925 and those models were also found not to be suitable for the Japanese soil. With further modifications to the Japanese designs using other tractor technologies from the USA, the technology spread through other Asian countries like Thailand, Bangladesh, Sri Lanka, India and the Philippines (Francks, 1996). With smaller 4-wheeled tractors becoming popular in Japan in the 1960s, the demand for power tillers declined but they

[3] Kilimo Kwanza is a Swahili phrase for 'Agriculture First' coined to represent the new drive for a green revolution in Tanzania

are still popular on very small farms. Their importance in Thailand, Bangladesh, Sri Lanka, India and China cannot be overemphasized. In the late 1990s and the 2000s, power tillers from the Japan, the Philippines, India and Later China were brought into the Tanzanian tillage technology mix. Though local manufacturing is insignificant, the importance of power tillers on small scale rice fields continue to grow in Tanzania.

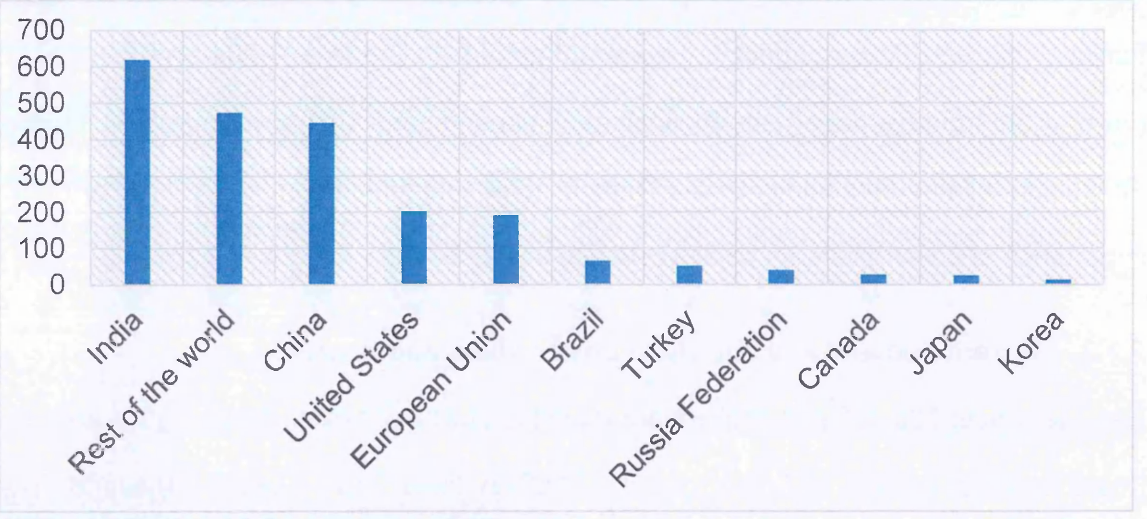
2.3.2 Current demand and supply of power tillers and tractors

Each year over 600,000 power tillers are manufactured worldwide. Of this figure, close to 300,000 are produced in China, about 60,000 in India and 70,000 in Thailand. The remaining 170,000 are accounted for by plants across the rest of the world. In Japan Kubota Corporation is the most popular manufacturer of power tillers. The main producers on the Indian market are VST Shakti and KAMCO. In China, Changzhou Dongfeng Agricultural Machinery Group Co, Zhejiang Sifang Group and Huaxing Machinery Co Ltd are the major manufacturers. In Thailand, Siam Kubota Industry Co Ltd[4], STI International Flying Star and Talaythong Factory Company Ltd are present.

When the global agricultural tractor market grew by 10% in 2013, 2.15 million units were produced into a market worth US$125 billion (Figure 2.6). India and China were at the top of this market producing 619,000 and 445,000 units respectively. This is followed by the US and the EU with a total of 201,851 and 190,000 units respectively. Other important producers are Brazil (65,115) and Turkey (50,320) (Agrievolution, 2014). The following Sub-sections look at the characteristics of the different segments of the global market in terms of the nature of demand and supply.

[4] A joint venture between The Siam Cement Plc., Kubota Corporation, Marubeni Corporation, and Min Sen Machinery Co Ltd

Figure 2.10: Volume of world tractor production, 2012 ('000)



Source: Agrievolution Alliance, 2014

a. North America and South America

There are two major centres of demand for farm tractors in North America: USA and Canada. These two countries have predominantly large scale farms. Farm sizes in the USA averaged 441 acres in 2002 and 418 acres in 2007 (USCB, 2012). Canadian farms averaged 728 acres in 2006 and 778 acres in 2011. These farms cultivate mainly sweetcorn and wheat for human and animal feed. However, recent demand for ethanol has increased the demand for these crops (sweet corn, especially) resulting in aggregation of farms. The share of their population in agriculture and its contribution to the national GDP is also very low. In the year 2000, 1.9% of the labour force in USA worked in agriculture and in 2002 agricultural GDP as a share of the total GDP stood at 0.7% (Dimitri, Effland, & Conklin, 2005). In 2006, the farm population accounted for 2.2% of all Canadians and in the same year, the share of agriculture in the total GDP stood at 1.6% (Statistics Canada, 2006).

Average incomes of farming households are also comparable to the national averages or even better. In 2004, the average farm household in the US had an annual net income of US$81,480, while the average U.S. household netted $60,528 (USDA, 2004). By contrast, In Canada, average income stood at Canadian $35,000 per farm, while the national average stood at $53,634 per household in 2006 (Agri-Food Canada, 2012).

The farms in Canada have grown bigger while those in the USA have experienced a slow reduction in size in the last decade. The demand for higher engine horsepower in these two markets also grew in the last century. The Nebraska Tractor Test Lab last year reported that the average and maximum horsepower of tractors tested at the lab has been increasing at a rate of 3% a year since 1950. Because of the larger farm sizes, farmers have relatively higher turnovers and profits that allow them to invest in high-end tractor technologies. Financial markets for agricultural investments also work well, giving farmers facilities that make long term investments in capital goods possible.

The main country in South America where the market of tractors is globally significant is Brazil. Brazil is the world's largest exporter of sugar, coffee, orange juice and soybeans. Brazil is considered as an important emerging economy in terms of global food security (Fan & Brzeska, 2010). It ranks third behind the US and Europe in overall farm exports. It is also one of the few places in the world where new land can be put into production. Over time South American countries like Brazil and Argentina are also experiencing an expansion in farm sizes and the structure of their production (especially soya and sugar cane) production is beginning to mimic their North American counterparts.

North and South American markets are dominated by three big groups of manufacturers plus other smaller players, and together they produce high end, high tech and high quality tractors. The top three brands are CNH (Case and New Holland), AGCO (Challenger, Fendt, Valtra and MF) and John Deere. Whilst their main target is to produce for the North American Markets, CNH, AGCO and John Deere do have plants across the world producing and serving high end markets in Europe, South America and other parts of the world (Hatibu, 2013).

The distribution of farms especially in North America clearly suggests that a substantial proportion of the tractors produced for these markets have higher horsepower (between 120Hp and 360Hp). Quality standards are also high. A combination of high quality and high horse power consequently results in high prices. Exports to other countries also targets farms which are very large. Small and medium sized tractors are mainly produced for the use by hobby farmers and large housing property management. There are also smaller utility tractors mostly supplied by Japanese, Indian and South Korean firms either with plants in the USA or in their home country. Their exports mainly target hobby farmers and environmental management companies with horsepower between 25 and 50.

b. European Union and Eastern Europe

The EU, in terms of value is the largest tractor manufacturer in the world, and is home to the single largest exporting country, Germany. In 2011 Germany had an export share of 21% of total world exports. Average farm sizes range from about 8ha in Italy to 54ha in in the UK. (Jörgensen & Persson, 2013). Though not as big as farms in North and South America, they are relatively bigger than those in Japan and South Korea.

The major manufacturers in this market are Case IH, AGCO, John Deere, SAME Deutz-Fahr, Argo and Class. Together these companies accounted for 85% of total sales in Western Europe in 2007. Both the production and demand is concentrated in Finland, France, Germany, Italy, Netherlands, Sweden and UK. The reason for the concentration of the markets here is the economies of scale in relation to farm size and the large horsepower (80Hp to over 200Hp) tractors produced by the dominant companies. Most tractors in these countries are used for about 4 to 5 years and then exported to the rest of the world as second hand machines, especially to Eastern Europe. Small tractors are gradually disappearing from the scene as farms become bigger and bigger. With new markets opening up especially on large farms in Russia, these companies are now investing heavily in research to improve quality, technology and size. For instance, in 2010, John Deere invested Euros 784 million in R&D corresponding to 4% of its sales volume (European Commission, 2011).

c. Japan and Korea

The average farm size in Japan stood at 2 ha in 2010 (MAFF, 2012b). This typically small average farm size stems from the post-war redistribution of land from large estate holders to small farmers under the land-to-the-tiller act which until 1970 limited land holdings to three hectares (Yoshikawa, 2010). Whilst mechanisation and competition increased farm sizes in most developed countries, in Japan it encouraged full-time farmers to shift to part-time farming. In Japan, less than 4% of the population is engaged in agriculture and the contribution of agriculture to national GDP is less than 2%. In 2010, farm household income, on a per capita basis, exceeded that of non-farm households by 21% in 2010. At that time non-farm households earned Yen1839, whilst that of farm households was Yen2230 (Jones & Kimura, 2013).

Korean agriculture is characterized by small farms. Although the average area farmed per household in 2005 was almost 50% higher than in 1970, it was still only 1.4 hectares. More than 60% of farms have less than 1 hectare and only 7% have more than 3 hectares. The share of agriculture in the national economy and in total employment is approximately 3% and 7% respectively in 2005 (OECD, 2008).

Despite the fact that farm sizes in Japan and Korea are very small compared with other regions of the world, they are very productive allowing farmers to accumulate enough capital for investment in machinery. Farmers in these two countries have financial surpluses that allow them to purchase high quality tractors and power tillers, but rarely large horsepower because of their farm size. Similar farming environments exist in Japan and Korea, though things are changing faster in Korea than in Japan. Both countries are engaged in the production of intensive cultivation of irrigated rice and over time have developed smaller but high quality tractors suited for their production situation.

The two common names in these markets are Kubota and Daedong. Producing both tractors and power tillers, a lot of research has gone into product development and improvement resulting in high quality products which are durable but expensive. The Japanese Kubota has a plant in Japan and several others in the USA specifically producing utility tractors for small farm usage and landscape maintenance. The Kubota Company is also collaborating with Siam Cement in Thailand to Produce Siam Kubota Power tillers. Just like Kubota, Daedong also produces tractors and power tillers for consumers in Korea and also operates plants in the US that produce relatively smaller horsepower machines.

d. India

In terms of volume, India is the worlds' largest producer of compact tractors and the country's output rose rapidly in the 2000s reaching an all-time high of 0.6 million units in the year 2012. It also doubles as the largest market for tractors in terms of quantity, exporting a little below 30,000 pieces of the total produced in 2012. Indian annual production represents about 33% of total global output by volume and it is expected to grow. According to the Annual Report, 2010–11, of the Department of Heavy Industry, Ministry of Heavy Industries and Public Enterprises, Government of India, "the Indian tractor industry is the largest in the world (excluding sub 20 HP belt driven tractors used in China), accounting for one third of global production."

There are currently 13 national and a few regional players in tractor manufacturing in India, M&M being the leading manufacturer. Other major players are TAFE (Massey Ferguson and Eicher), ITL (Sonalika), Punjab Tractors ltd., Escorts, John Deere, New Holland India, HMT, Forcemotors, Mahindra Gujarat. However, the market share is concentrated amongst the top-five manufacturers, accounting for over 90% of total volumes. M&M which currently controls about 40% of the Indian market is also becoming an important global player and competes with traditional household names like Kubota in the US.

The 2001 Census of India indicates that farming in India is very small scale - 68% of farms are less than two acres in size and 95% are less than five acres in terms of owned holdings. With high population growth rate, and expanding households and household sizes, farm size in India have fallen from 2.3 ha in 1970 to 1.4 ha in 1996 on average and continues to decline (Chand, Prasanna, & Singh, 2011). Thus tractor manufacturers concentrate on the production of small to medium sized tractors ranging from 20Hp to 50Hp. Farmer demand for tractors in India is influenced positively by factors such as support from the Government of India for rural development and agri-mechanisation; scarcity of farm labour especially during the sowing season; increase in credit flow to agriculture; increase in non-agricultural application of tractors as in infrastructure projects; growth in niche power tiller segments and untapped territories; besides healthy export sales.

India tractor exports are targeted at markets which demand medium sized machines just like in their own country. For instance exports of Mahindra and Farmtrac to US are in the range of about 30Hp to 60Hp, targeting hobby farmers and managers of utilities such as golf courses. In Pakistan where farm sizes are not very different from those in India, Millat Tractors has been assembling small to medium sized Massey Ferguson tractors for the local markets mainly, and in recent times has started exporting to other countries with similar farm and farmer characteristics, especially in SSA. Though the quality of machines produced in India and Pakistan are not as high as those from Europe, North America they are relatively simpler in terms of technology.

e. China

The collective agricultural system in China was dissolved in 1978. At that time, community administrations in charge of land management allocated an average of 2ha of land per household. This allocation made farm lands more fragmented and smaller making farm mechanisation on these fields difficult. This kind of land tenure arrangement for the household could be held for a period of 15 to 30 years and then they could ask for a renewal from the community authorities. With the Chinese industrialization and opening up in the 1990s and 2000s, rural labour supply became scarce as young people who worked on the agricultural lands preferred to move into the urban centres for manufacturing and related jobs.

As labour shifted to urban centres, households losing labour to migration naturally relinquished their farmlands to others who decided to stay and continue farming. In addition, with liberalization of the land markets, it is now possible to rent or lease land. A combination of these developments has allowed farm sizes to increase again and to justify the case of mechanisation. Nevertheless, the average farm sizes continue to be much smaller than those in North America and Europe. Increased farmer income, availability of credit and government subsidies has further strengthened the drive to mechanisation.

In terms of manufacturers, CFT and Foton Lovol control 43% of the market, with 46% of the remaining 57% shared among Yueda, Benye, John Deere, Donfeng and SNH. The 11% share left is occupied by smaller firms. To meet the demand of the market, driven by relatively smaller average farm sizes in the country, most of these companies produce tractors and power tillers of up to about 20Hp (mainly power tillers). For this end of the market, China produces about one third of the total units produced across the world. Some of these power tillers are exported to India and other Asian countries as well as Africa, including Tanzania. The quality of these small machines are much lower than those from Japan or South Korea, however prices are lower.

2.3.3 Where should Tanzanian farmers look?

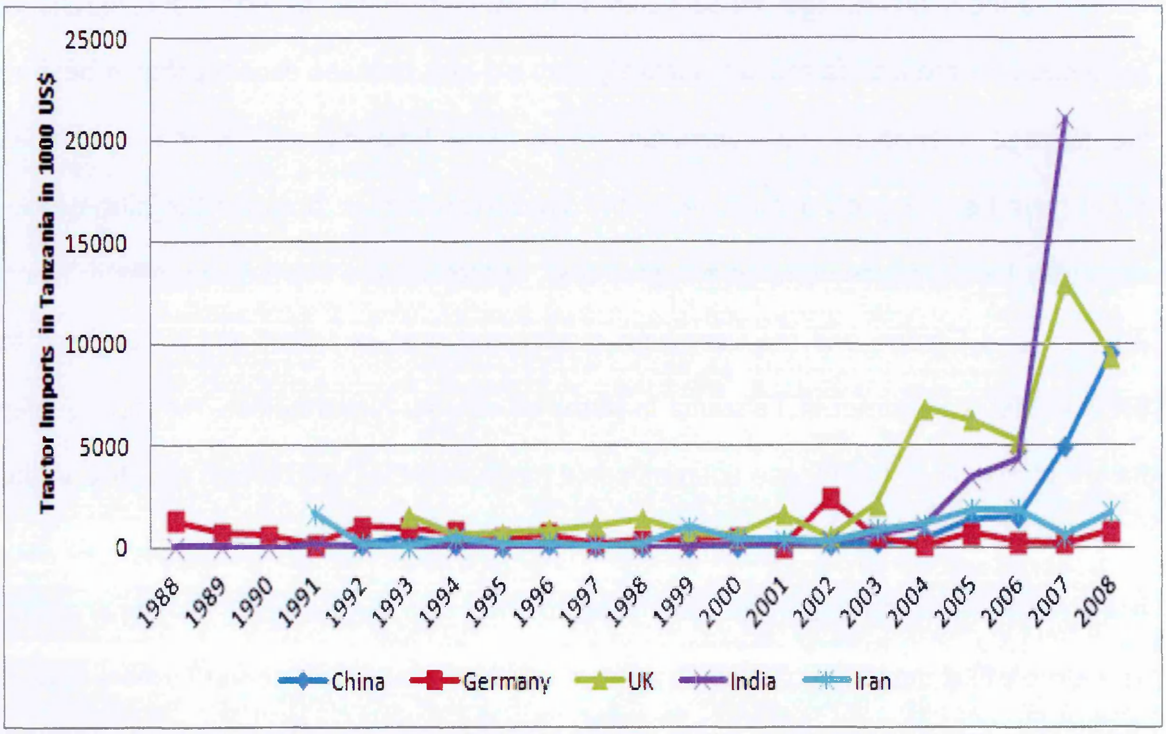
North American, South American and European farms are several fold bigger than Tanzanian farms on average. Japanese and Korean farms are relatively smaller and comparably similar to those in Tanzania. However, American, European, Japanese and Korean farmers are several times richer than the Tanzanian farmer. Thus machines produced for American farms are relatively very big and possess capacity that is beyond the average needed by the Tanzanian farmer. The Japanese and Korean machines could have been a good alternative for the Tanzanian farmer; however the high quality machines they produce come at a higher cost. Therefore, the scale economies in North America and Europe and the very high quality and cost in Japan and Korea tend to exclude the poor farmer in Tanzania in terms of access. Nevertheless, the high quality nature of machines from these sources could mean that they will be cost effective in the long run for the Tanzanian farmer. In addition large scale farmers in Tanzania may also need such large and expensive machines to meet the demands of their operations. Therefore whilst their high cost nature may mean that smaller and poorer farmers cannot afford them, there are some participants in the farming business who may need them for scale reasons.

The Tanzanian terrain is similar to those in India and China in terms of farm size and farmer incomes. There is however a division of labour between the two countries. Whilst the Indians dominate the production of medium-sized tractors, the Chinese are more engaged in the manufacture of power tillers. Therefore it is possible for the Tanzanian farmer, especially the smallholders to consider India as a source of tractors, whilst they also consider China for walk-behind power tillers.

The possibilities in terms of choice between MM and EE sources will be discussed in detail for most part of this thesis. Figure 2.11 suggests a trend that may be a pointer as to what choices are currently being made in Tanzania. That is, there is a current shift from the importation of tractors from Europe to importation from China and India into

Tanzania. This change in the source of imported tractors became more visible in the mid-2000s. We shall concern ourselves in establishing some of the push factors of such changes and how they are affecting choice of technique in Tanzania.

Figure 2.11: Tractor Imports into Tanzania, 1988-2008 (US$ '000)



Source: Generated from WITS database, 2011

2.4 Conclusion

Though agriculture's contribution to GDP in Tanzania is not as high as services, it plays a crucial role in terms of employment, especially in the rural areas. Output in terms of annual crop production per capita is declining. This is an indication that labour productivity is falling in the agricultural sector. Such trends are associated with long term unemployment and food security risks which call for policy attention. To move production levels beyond the current state without altering the factors of production, technology needs to change. One of such technologies which could be modified is those related to primary tillage- moving from simple tools to machines (power tillers and tractors).

There is however a paucity of both institutional physical infrastructure that supports the agricultural sector, including agricultural technology transfer. These sets of infrastructure, especially those related to financing of the agricultural sector are unlikely to change dramatically in the next few years. This calls for creative ways of using the little available to make the most out of the present situation. The world market for tractors and power tillers is growing. Currently, China and India have become important producers in the market. The presence of China and India on the global market has created a wider choice for farm machinery. Trade ties between Tanzania and China, as well as India continues to grow; and it is within this framework of continual trade growth that capital goods for farmers could be harnessed to support the predominantly low tech farming systems in Tanzania. In the next Chapter, we explore the global innovation landscape, and how specific changes which are occurring in the way in which innovations are created and the shifting geography innovation landscape could influence technical choice on Tanzanian farms.

Chapter 3 : Innovation, Technological Choice and Technology Transfer

3.1 Introduction

This theory Chapter discusses the importance of agricultural mechanisation in SSA. The Chapter seeks to understand why mechanisation efforts on the continent have generally not yielded the desired outcomes. Having established how important technology is we demonstrate that there is a change in the global innovation landscape. We are witnessing a shift in the geography of the centres of innovation generation and development from the *Global North* to the *Emerging South* and this change might offer new opportunities for SSA producers to realise their mechanisation potential.

A spread in the centres of innovation might also suggest that the technology choice sets from which SSA can select are widening. Thus there is a choice to be made, but this must be an informed choice. An understanding of how this choice is made is crucial, if benefits to the farmer are to be maximised. We therefore give a brief exposition on what constitutes appropriate technology and technique choice. The factors inducing technical change and the biases that come with technical change are then considered. We argue that whilst appropriate technology movements in the past emphasised acts of charity as a means of technology transfer to developing countries and had limited success, the new wave of innovations from the emerging south presents a profit-driven Schumpeterian motor that may hold the key for success.

The final discussion of this Chapter considers the processes through which technology is transferred and the role played by government in ensuring that market imperfections are minimized within the context of absorptive capacity. We shall begin with agricultural mechanisation and rural development in the next Section.

3.2 Importance of mechanisation in SSA

SSA countries have long recognised that agricultural mechanisation had the potential of transforming the rural economy into a viable engine of growth and in response many

African states at independence spent resources in trying to develop agriculture through tractor imports (FAO, 1966). Mechanisation has the potential of increasing area under cultivation and also freeing labour to concentrate on other aspects of the farming process which enhances productivity (Irz et al., 2001). The resultant increased productivity from growth should translate into increased employment, food security and poverty reduction all things being equal (Mellor, 1999). However for the past 40 years, efforts targeting the use of tractors and especially on small farms in the region have not worked (Hatibu, 2013). More recently, an assessment of the provision of government subsidies for the establishment of private sector run mechanisation centres in Ghana revealed a mixed impact on different outcome indicators. For example, whereas the program has contributed to improving availability of mechanization services, reduced drudgery, promoting adoption of good practices, and raising yield, it has had no impact on the change in the prices paid by farmers for the services used and the change in the amount of area ploughed. (Benin, 2014).

Several reasons have been advanced in the farm mechanisation literature for the failure of African governments and farmers to push mechanisation to optimal levels. Infrastructural factors, capital constraints and the nature of, and choice sets of technologies available were some of the factors cited for such failures (Sims & Kienzle, 2006). More importantly the profitability of mechanising agriculture is also critical. In both Mali and Ghana, there is agreement that mechanisation is profitable and hence economic for crops with a good or fair local market price and ready market (Fonteh, 2010).

There were also debates about the intended and unintended outcomes of mechanisation on employment (Biggs et al., 2002). Many writers argued that mechanisation will leave rural farm labour unemployed; others argued that mechanisation had the potential of improving productivity outcomes (Eicher & Baker, 1982). The debate became more focused on whether it was a good thing to mechanise instead of concentrating on which forms of mechanical technologies were viable (ILO, 1973). Proponents of mechanisation argued that the use of tractors and draught animal could increase productivity of land through timeliness of farm activities; overcoming seasonal labour shortages; reduction of farm drudgery and could also be used for other off-farm activities (FAO, 2011). A seminal paper by Giles of North Carolina State University showed that together with other farm inputs, farm power influenced agricultural productivity and production in general (Giles, 1967). This paper became widely accepted and influenced the mechanisation debate across the world. It appealed to newly independent African countries including Tanzania to emphasise mechanical farm power (IBRD, 1960).

Experts in the development community who opposed the above views argued for a cautious path of mechanisation as it could lead to displacement of labour, landlessness, rural-urban migration, inequitable distribution of wealth and increases in absolute poverty (ILO, 1973). They argued for a gradual transition from hand tools, to improved implements and animal power, moving in tandem with changes in the technological, cultural and socio-economic development of society (Mrema, Baker, & Kaha, 2008). Further work undertaken by the ILO between 1970 and 1973 supported the potential unemployment effects of mechanisation. However recent studies have shown that specific patterns of rural and agricultural mechanisation created net positive effects on productivity and income distribution (Mandal et al., 2002). Again the thinking that unemployment will be exacerbated if farms were mechanised failed to recognise the distinction between drudgery intensive technologies and skill intensive technologies (Biggs et al., 2002). That is, retraining the labour freed from highly drudgery-based activities could prepare them for different forms of employment related to the mechanisation process (Jackson & Palmer-Jones, 1997).

Deteriorating economies across SSA and the consequent liberalization of the productive and markets sectors led by the Washington Consensus (Williamson, 1990) derailed mechanisation objectives of many African governments in the 1980s and 1990s (Gabre-

Madhin & Haggblade, 2004). However, it was not the only the Washington Consensus policy that caused decline in interest in mechanisation. That is, there were also several policy initiatives by developing country governments underpinned by a linear pathway to mechanisation thinking which did not work and caused further slow-down in spending on mechanisation (Starkey, 1998). This thinking, suggested by some engineering and social science literature at the time, made many developing countries assume that mechanisation is a stage by stage process (Gass & Biggs, 1993; Biggs et al., 2011). Some of the views against rapid mechanisation argued that until the social, cultural and infrastructural settings improved it will be wrong to employ mechanical tools on farms (Mrema et al., 2008).

With mechanical power, tractors mostly imported from advanced countries unable to create desired growth paradigms, development communities turned to other types of technologies. More attention was paid to the proponents of gradual mechanisation. Thus In the late 1970s and 1980s, efforts aimed at intermediate tractor technologies supported by the tenets of appropriate technology movements[5] gained grounds. For instance *Kabanyolo* and *Tinkabi* mini-tractors respectively in Uganda and Swaziland were developed (Holtkamp, 1991). Not fully supported by international policy, the success rate was low and these efforts ended in the 1990s. However, overall efforts to promote animal traction fared better (Starkey, 1998). A review of material related to the gradual progress on the mechanisation ladder made it quite clear that there is no fixed set of stages to be followed when considering mechanisation. Different processes may be mechanized at different times for different reasons in different places, with different actors playing different roles in each situation (Biggs et al., 2002).

In another development, an analytical literature review by Pingali et al. (1987) complemented by field visits to 50 locations in 10 African countries including Tanzania

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[5] The main tenets of this movement was that if low cost and small scale technologies were made available to developing country producers and these producers in turn produced affordable consumer goods for the poor, then higher growth, poverty reduction and improved distribution would result.

revealed that it has been impossible to use tractors to accelerate the evolution of farming systems on the continent because of the nature of land and its resources being cultivated by farmers. In many areas, farms are typically forest fallow and virtually impractical to introduce tractors. Tractors only become popular at the late bush fallow stages or early grass fallow stage of evolution. The study further suggests that the introduction of tractors at the late bush fallow stage or early grass fallow stage is not cost effective in comparison with animal power. The study argues that at this point, the cost of maintaining animals reduces since there is an abundance of forage for animals to feed on. Thus the persistent failure of tractor hire schemes introduced by some African governments and donor agencies could be explained by a combination of these factors.

3.3 Changing economic fortunes of SSA and the emerging economies

Regardless of the divergent views on the benefits and challenges of mechanisation access can only be created if farmers have the requisite financial standing. And as discussed in the previous section, many SSA economies performed poorly in the 1980s and early 1990s. However, the good news today is that stability and growth are being restored in many SSA countries including Tanzania. Specifically in the last decade governments of SSA countries where rapid growth has occurred are rethinking mechanisation (FAO, 2011). For example, since 2007 the government of Ghana has provided subsidies for private businesses and farmers to set up tractor hire service (Houssou, et al., 2013)

This second look at the viability of mechanisation and the need for policy is happening at a time when the world order of technology generation is shifting from the traditional North to South. Globally, Emerging Economies like China and India are becoming an important force to reckon with in terms of capability and competence in producing consumer and capital goods especially for low income markets (Clark et al., 2009). These emerging economies are using cost innovations to produce consumer and capital goods that are accessible to low income populations at the bottom of the income pyramid (Zeng &

Williamson, 2006). This new dynamic may hold the key to unlocking the challenge that has prevented poor producers (farmers) in SSA from using mechanical tillage technologies on their farms (Khan et al., 2009), a matter we shall consider in the next sub-section.

3.3.1 New possibilities for revamping the sector and choice of technique

SSA's recent mechanisation policies are occurring in a dynamic world. The rise of China and India as global economic and political powers is one of the most important transformative processes of our time - challenging the international political economy dominated by the "transatlantic West." Recent literature on the engagement between China/India and SSA suggests that there could be diverse impacts on African economies as they open up to, and relate with these emerging economies through trade, aid and production/FDI. The distinctive and significant impact which these emerging economies are likely to have on the global economy and SSA in particular, are likely to arise not just from their size, but also from their distinctive public and private actors (Kaplinsky, 2008). The impacts that these engagements are likely to have on SSA could be competitive or complementary; whether it is through trade, aid or FDI. The complementarities or competitiveness will either be observed directly or indirectly on consumers and producers within SSA countries or in third countries outside the particular SSA economy (Kaplinsky et. al., 2007; Khan & Baye, 2008; Morris & Einhorn, 2008). We consider some the studies which have attempted to examine this matter in the next sub-section.

3.3.2 Empirical studies

Studies in Africa on the direct effects that SSA trade engagement with China and other emerging economies are having on African producers and consumers have largely ignored the impacts that capital goods may have on producers on the continent. For example, using three case studies in Cameroon, Khan, et al. (2009) found that imports of consumer and transportation equipment (motorcycles) from China had both positive and negative impacts on local consumers and producers. In the direct sense, cheaper consumer goods from China created access for the poor who otherwise could not afford locally manufactured products or those imported from developed economies, like the EU. Further, relatively less expensive motorcycles have not only eased the burden created by a malfunctioning public transport system and poor road infrastructure, but also created jobs for the drivers. There are however concerns about increases in the number of road accidents and the stress created for policing and public health service. In terms of effects on third country markets, the same study finds that hitherto, producers of batteries in Cameroon were able to export to other African countries, but such markets have been taken over by low cost Chinese products, resulting in cut backs in local employment.

Morris and Einhorn (2008), when studying the South African clothing and textile sector found that the competitive and complementary, direct and indirect impact of Chinese imports on industry is complex and multi-faceted. Productivity increases in production were observed as a result of increased competition. There were equally lower logistics costs to producers as a result of improved efficiency and infrastructure as well as diminishing bureaucracy. The informalisation of the sector has also resulted in falling real wages. There are also falling prices of imported inputs and changes in the distribution of rents along the value chain. Unemployment fears could not be justified to the extent that new forms of jobs have been created for new actors within the chain, who otherwise could not have participated.

A more recent pilot study by Mmari & Mpanduji (2014) directly related to agricultural mechanisation concentrated on understanding the role of frugal innovation[6], technology transfer and technology networks in Africa's economic transformation. Using the power tillers and small farmers as objects of the research, the study identified the process through which machines were imported (how choice was made), the role of government

[6] Frugal innovation is viewed as a process of transforming products from their technical complexities while retaining their basic functionality, plus reduction in aspects of costs to make them more accessible to the poor.

and other market institutions which coordinated to facilitate the process. The study concludes that import of power tillers into Tanzania was state-led and was not adequately informed by technical and agro-ecological differences. As a result, power tillers were imported from different Asian countries and no reengineering was carried out in their designs to suit the local needs.

In addition, no thorough preparation was put in place in terms of identifying the needs of users, training of operators, and setting up maintenance and service system. The study suggests that frugal innovation entails more than just reducing the complexity and costs of products or services while retaining basic functionality. It also entails a functional interface between technological and institutional dynamics. This study by Mmari & Mpanduji (2014) did not examine appropriateness through the computation of productivity and profitability measures of the different power tillers from the various Asian countries. This is an area which our present study will seek to contribute to and also expand the thesis beyond power tillers to include tractors.

Finally, (Biggs et al., 2011) in sketching the diverse patterns of rural mechanisation in South Asia, first called for a reopening of the mechanisation debate in the developing world which had been left dormant for almost two decades. In the view of the writers, under some demographic projections, neither local urban development nor the growth of the international remittance economy will provide adequate employment for rural people. The role of engineering, energy and trade policy in influencing patterns of agricultural and rural mechanisation and employment remains central. In the account of the study, despite the high level of the agricultural engineering industry in Japan, Korea and India, they failed to develop machines that would improve the mechanisation levels in developing countries in Asia. It was the Chinese industry which has created technologies that have transformed small scale agriculture in Bangladesh, India and Nepal. In each of these countries an initial entry by the high quality versions of power tillers from Japan are followed by relatively lower quality versions from China, which are more affordable to the user.

In conclusion, the Biggs et al., (2011) study draw attention to four themes that provide entry points into a renewed debate about agricultural mechanisation (1) the important role played by public policy and it's diverse outcomes; (2) the significance of increasing markets for technology-based services; (3) the importance of revisiting income and asset distributional outcomes produced by technological change; and (4) the need to link up "old" themes around technology with current realities. Aside from this thesis seeking to empirically test the extent to which Chinese and Indian technologies are more profitable when compared with their Korean and Japanese counterparts, we shall also attempt to contribute to themes 1, 2 and 3.

Clearly these studies have tackled some aspects of the potential effects that SSA engagement with Emerging Economies can have on African producers. However, the all-important area of what benefits producers can accrue in terms of the use of Emerging Economy capital goods has not been given the needed attention- a matter this study hopes to address..

3.3.3 Changing innovation landscape

To contribute to the debate on how emerging economy capital goods can contribute to productivity growth of poor producers in SSA, an understanding of how technology drives economic growth is essential. The discovery of the Solow residual in 1957 in US manufacturing showed that the rate of economic growth could not be totally explained by known causal variables. Only 12.5% of the improvement in productivity, after taking into consideration the stock of capital and labour, could be accounted for. Thus, beyond the rate of investment, other factors also influenced productivity; particularly science and technology (S&T) investment. This drew the attention of policy makers and researchers then, to the usefulness of S&T to economic growth, and the consequent impact on underemployment and unemployment which underlies poverty and inequality across the globe (Clark, et al., 2009).

Thus the potential contributions that S&T could make in addressing poverty and inequality were without doubt. However, how to make this happen kept the development community busy in the 1960s and 1970s. During this period, when a group of social scientist were asked for recommendations by the UN on S&T for development in low income countries, the scholars proposed what is now known as the Sussex Manifesto (SM). The SM argued that S&T development was overly skewed to advanced countries. As a result high levels of human capital were built up in advanced countries or advanced sectors in developing economies with very little positive effect on local economies. As an antidote, the SM suggested that beyond institutional change within and outside the S&T systems, developing economies should raise their R&D expenditure to 0.5% of GDP. In addition developed countries should support R&D of low income economies through aid, and spending a portion of their own R&D efforts to meet the needs of developing countries (Singer, et al., 1970).

At the time (1960s) when the SM saw formal public sector R&D institutions as the major source of innovation, only one-fiftieth of global R&D was located in low income countries. In the year 2000, the figure stood at one-fifth: representing a tenfold increase. However, these phenomenal increases in R&D expenditures in developing countries failed to change the state of innovation capacity in many low income economies. Because the technologies so developed relied heavily on advanced country inputs, they were usually inappropriate for poor consumers and their operating environments (Clark, et al., 2009). To deal with these shortcomings, the appropriate technology (AT) movement led by Schumacher suggested widening the range of efficient techniques to include mainly less capital-intensive innovation (Schumacher, 1973). The AT movement did have some recognition, but failed to address the challenge of shifting the production of technologies from supply-driven to demand driven to meet the needs of consumers in low income countries (Kaplinsky, 1990).

Some of the challenges that might have caused the failure of the AT movement, lies in the seemingly concentrated nature of technology generation in the advanced world. Over the past two or three centuries, the dominant source of technological change and innovation has been in Europe and North America, joined in recent decades by a group of north-East Asian economies (like Japan, Korea and Taiwan), increasingly integrated into large-volume global markets (Kaplinsky, 2009). However, several decades of investment in education, training and capital goods sectors in emerging economies like China and India have helped them develop science and technology capabilities for innovation (Mani, 2005). These economies have dynamic markets which are growing in terms of size and purchasing power. This allows for innovations to reap economies of scale and scope. The market is however distinctive in the sense that it is dominated by low income consumers with associated trade-offs between cost, quality and variety. Low labour costs also allows for less mechanised forms of production. Infrastructure is generally poor and unreliable, and labour relations are also different. These characteristics of the emerging economy markets have triggered the development of Below the Rader Innovations (BRI)[7] which may go unnoticed. Because the nature of these markets and production has been around for a long time, BRI tenets anticipate that they will produce appropriate technologies that are suitable for production skills and technological capabilities in other low income countries. (Clark, et al., 2009).

At the very least, BRI innovations could complement the technologies available to poor country producers, or possibly find more space because of the social and cultural context within which they have evolved. Insights into how distinctive they are from advanced

[7] A term pioneered by Raphael Kaplinsky and other researchers at The Open University to emphasise the point that some technological innovations, both rudimentary and advanced, which usually go unnoticed may hold the key for providing access for low income consumers to products and services which they might otherwise not have.

country technologies and the extent to which they are pro-poor is crucial. Studies which target this area of research are relevant for two reasons. First, technological innovations do not always follow a sequential process of generation, transfer and diffusion, but are usually socially constructed. Thus a technology generated by a particular social context is more likely to be suitable for other societies which share similar characteristics, as opposed to if they were developed in a completely different social environment. Second because China and India are themselves developing, just like other SSA countries, they are likely to develop technologies (capital goods) which are suitable, not just for their own operating conditions but also for other developing countries with similar social, cultural and economic contexts.

As the Emerging Economies join Advanced Countries to produce capital goods (such as tillage technologies), the fundamental question of choice of technique becomes imperative for users and SSA governments. The innovations and technique choice literature in the past four decades has been dominated by how appropriate advanced country technologies can be useful for the developing world (Bhalla, 1977; Stewart, 1977; Kaplinsky 1981; Clark, 1985; Kaplinsky 1990). Whilst most writers concentrated on a comparison between advanced country technologies and indigenous versions, it is now imperative that we do the same for the advanced country and emerging economy dichotomy. In much of the growth literature, the distributional consequences of technological progress and innovation are generally ignored (Cozzens and Kaplinsky, 2009). Therefore, this study will not end with just a comparison of the distinctiveness of the two sets of techniques (advanced country verses emerging economy), but also concentrate on the extent to which they are pro-poor. In the meantime let us start with a discussion on how choice is made.

3.4 Optimality and appropriateness of technology choice

In any production process, there are infinite possibilities of technically combining labour and capital to produce an output (Farrell, 1957; Sen, 1968). However, because of engineering limitations not all technically possible combinations of labour and capital are feasible (Eckaus, 1955). Economically optimal technique choice is therefore constrained by a set of limited engineering production functions (Clark, 1985). Depending on the prices of labour and capital in the society under consideration an economically optimal choice of technique can be made with the view of minimising total cost. Depending on the size of the market in which the production process is taking place, there are also scale considerations to be made (Kaplinsky, 1990). That is though there could be scale economies to be realised, if the market under consideration cannot absorb all what is produced, then the producer may have to cut back on total product. Further, depending on the characteristics of consumers (rich or poor), the quality of products must either be high quality or low cost to cater for the purchasing power and demands of buyers. Historically, the production of *efficient* technologies was concentrated in advanced countries where capital is relatively abundant. This narrowed the range of economically efficient technologies for labour abundant developing countries (Emmanuel, 1982).

For technologies to be considered appropriate environmental, cultural and employment concerns of society must be given some attention when a choice of technology is being made. Societies who are final consumers of technologies may also demand that whatever technique choice is made the health of the environment and user satisfaction are catered for. The technological choice should also take care of employment objectives of society to the extent that unemployment is curtailed. Appropriateness is thus a relative concept influenced by the objectives of the decision maker (Floor, 1979)

Economic agents (households, firms and governments) across the world of decision makers have different goals and face different constraints in terms of resource availability, prices, type of consumers and other environmental standards. The choice of a technique from a stream of available ones depends on the goals of the decision maker, the constraints they face and the characteristics of the techniques. Thus an appropriate technology can be a normative one depending on whose welfare is considered or a positive one reflecting economic and climatic conditions in which the technology is to be utilised (Lipsey, 1966). The actual decision therefore varies according to the nature of the decision maker and for the economy as a whole.

Richer societies (advanced countries), have capital intensive techniques and relatively poorer ones (developing countries), which have labour in abundance usually have labour intensive techniques. These two markets have different requirements in terms of technology needs based on the fact that the availability of capital in advanced countries is high and comes with relatively lower interest rates. In the developing countries, labour costs are relatively lower and there are often lower levels of skills. In any given environment, a set of techniques which makes optimum use of available resources is considered appropriate. For each process or project, it is the technique that maximises social welfare if factors were shadow priced. This concept deals with the inter-relationship between patterns of human living and technological choice. That is the role that technology can play in meeting the needs of various segments of society. (Kaplinsky, 1990).

The creation and provision of techniques (capital goods) was formerly dominated by advanced countries making the efficient technologies produced disproportionately suitable for developed economies or the developed sectors of developing countries (Eckaus, 1987; Emmanuel, 1982; Stewart, 1977). For many years the developing countries had to adopt and use these technologies sometimes without modifications to suit the local requirements. With new forms of capital goods being developed by emerging economies, what criteria will ensure that the selection made accounts for the welfare of the decision maker, society and the environment especially in SSA?

Kaplinsky (1990) makes a number of recommendations that may help determine what considerations to be made if appropriate technologies are to be made. The *organization of production of the firms; income levels; skill limitations; products and linkages or* *technical factors* are key elements to be considered. If the production organisation is such that firms are bigger with many employees and producing at a large scale then the scale of technologies developed should be commensurate with firm/farm size. Income per capita is an important determinant of what the average producer or consumer in an economy can pay for a product and will influence the pricing of capital goods produced for those markets.

Different technologies may also require different levels of labour training and skills to man them. Though some individuals within a society may have very high skills, there are general trends of what the average person can do as a reflection of the education system and investment in skill development. This too, must be given attention when developing technologies for a particular society. Attention must also be given to the kinds of products developed and whether they fit the environment in question. For instance whilst tractors developed for temperate regions may require a glass cabin to protect users from cold, no such thing will be needed in the tropics. Again technologies will fit a society if there is an existing infrastructure and institutional support that would facilitate its use. Where there is paucity of infrastructure, there may be the need to consider technologies which are more robust and can depend on stand-alone structures to work.

Stewart (1977) argued that technological development has been such that it creates inappropriate techniques, and leaves underdeveloped and undeveloped the techniques which suites conditions in poor countries. As such she argues that a technology that targets the rural economy in the developing countries should aim at increasing labour productivity, keep technology within the capacity of the local entrepreneurs, minimise skill requirements. It should also provide employment for local labour and through the use of local inputs stimulates several productive activities within the society. In the urban societies of the developed countries where firms are engaged in large scale production and adopting cutting edge technologies in an attempt to fit into a more globalized market place appropriateness may take a different tone. Appropriate technology should increase access by local entrepreneurs, increase employment opportunities, develop the existing knowledge that firms have and gradually transform them from a dependence stage to firms which also produce innovation. (Stewart, 1977).

To address the needs of relatively poorer households and countries as they access technology for production and consumption, the appropriate technology movements in the 1970s and 1980s promoted intermediate technologies that were low cost and smaller in scale to meet the infrastructure and skill circumstances of the poor. These movements were generally based on acts of charity. The tenets of the appropriate technology movements led by Schumacher were based on the idea that growth, poverty reduction and distribution in low income countries will be greatly enhanced if producers had access to labour-intensive technologies which were small in scale, and if they produced products which were low cost and accessible to low income consumers (Kaplinsky, 2009).

The absence of entrepreneurship in low income countries, inadequate skill sets to develop innovation and the lack of effective demand made the ideas of the appropriate technology very difficult to implement. The producers and consumers in low income countries had unfilled needs, but they lacked what it takes to meet these needs. However, in the last two decades some of these limitations of the appropriate technology movement have seen significant changes, especially in China and India. Entrepreneurship in these two economies have become vibrant, skill sets have improved thanks to heavy investments in training and skill development and as incomes also rise as a result of high growth, effective demand is soaring. These changes could enhance technical change in other developing countries by circumventing the need to use charity as the main engine of technology transfer. We shall consider some of the inducements to technical change and the factors that may influence the direction of technical change (technical bias) in the next Section.

3.5 Induced technical change and technical bias

Movements along the production function from one point to another represents a change in technical choice. However, if the whole production function shifts towards the origin, there is a technological change. Basic neo-classical economic theory suggests that the rational producer will use each input to the point where the marginal productivity of that input equals the unit price of that input (Mowery & Rosenberg, 1998). However, there are other factors that may induce technical change aside from the usual equation of cost of output and input prices. As noted by Ruttan (2001) both demand and supply factors can induce technical change. First when the nature of demand changes, there is the likelihood that technology leaders will innovate to meet the demands of the new market. Consider the incomes of consumers in a spectrum. When high income consumers induce innovation it results in the choice of highly-differentiated "positional" products, commensurate with the status of the consumer. Emphasis is placed on quality rather than just price and acquisition costs. On the other hand, low income consumers need function, rather than "position", they are prepared to settle for low quality low acquisition costs. (Prahalad, 2005; Kaplinsky, 2009).

Second, when a particular input becomes expensive in a particular production environment, firms will use less of that input and more of the relatively abundant one. That is the change in the relative price of the factors of production is itself a spur to innovation and to inventions of a particular kind. Thus innovations will be directed at economising factors which are becoming more expensive. (Hicks, 1932; Ruttan, 2001). Future expectations about changes in factor price could also drive innovation and the direction it takes (Fellner, 1961).

The third factor inducing patterns of technical change relates to the trajectories of innovating firms. Firms will have imperfect information and will scan their known contacts and data-sources in the search for improvements in process and products. They will also do so in the context of the routines which they have developed to master their past operations. These firms thus have their own path-dependencies and trajectories (Dosi, 1982).

Regardless of the source of technical change either more of labour or less of capital or vice versa would be saved (Clark, 1985). In a developing country context therefore, attention must be paid to technologies which takes into account the incomes of consumers or users as well as the availability of factor inputs. Under labour abundant conditions typical of some of the sectors in developing countries, capital saving technologies (that is technologies which are labour bias) might be preferred to those which are capital biased.

3.6 The measurement problem: contribution of K and L to productivity

Since this study intends to compare technologies on the bases of their contribution to growth and productivity, there is the need to measure the efficiency of capital (K) and labour (L) use. Whilst theoretically it is relatively easy to discuss technology and technological choice, the actual measurements of what an efficient technology is, can be very difficult in the real world. It makes both theoretical and policy sense to measure efficiency. To subject the theoretical arguments like relative efficiency to empirical testing, actual measurement of efficiency is required (Farrell, 1957). However various methods have been suggested and used by scholars in the area of technical choice. Prominent among these methods are physical productivity ratios of labour, capital and output (Stewart, 1977). The challenge with this method is the limitation imposed by heterogeneity of products and the fear that sometimes we may not be comparing like with like. In cases where these differences can be brought to a minimum, technologies are ranked based on their capital or labour intensity and sometimes the productivity of capital or labour. To support the results that are obtained from these productivity coefficients, further analyses which rely on profitability using benefit-cost analyses have also been widely employed in the literature.

Productivity of inputs (that is the contribution of inputs to output generation) can either be done in the total factor sense or a single factor sense. Total factor productivity is defined as the ratio of the value of output to the value of all inputs. It gives an idea of how productively inputs are used. To facilitate ease of calculation and isolate individual contribution of different resources, the analysis is carried out in terms of single factors, either L or K. For labour, the average productivity is defined in terms of output per worker over a given period of time.

The different measures, either total or individual factor productivity, can give quite different results. It is possible for total factor productivity to fall, while labour productivity is rising. It is important thus to be clear and consistent when using these forms of measures. In measuring contributions of labour and capital to productivity, ratios of the three basic variables of the production function are used, mainly to examine how intensively a factor is being employed. The Capital-Labour ratio (K/L) refers to capital per unit of labour employed; that is the extent to which the two factors of production are being used relative to each other. Output-labour ratio or the output per worker – (O/L) is a measure of labour productivity. Output-capital ratio which is the output per unit of capital (O/K), on the other hand, measures productivity of capital.

The accuracy of these ratios depends on the extent to which factors and output are correctly measured. In theoretical analysis especially from neoclassical perspective, measurement is not so problematic. The neoclassical school argue that abstraction from the real world can be made based on some assumptions: (i) Homogeneity of factors and products; (ii) Perfect competition of markets (in terms of both factors and products). Thus based on the homogeneity assumption, calculating O/L for example, only involves finding the ratio of the sum of output to the sum of labour. However in reality, some problems exist when one is measuring factors and outputs of production. Factors, that is, labour and capital are not homogenous in the real world. In addition factor markets are not perfect – as a result of information asymmetry, monopoly control of resources, minimum wage policies, etc. Therefore, factor prices cannot be used as weights in creating indices (See Kaplinsky, 1990).

On the product front, the non-homogeneity problem of products cannot be overlooked and a linear sum of product value will be misleading. Product quality and other forms of product differentiation such as packaging and standards inherent in the product are different. The same kind of product coming from different firms from the consumers' perspective may be different and as such valued differently. For Example Divine chocolate and Golden Tree chocolate all produced in Ghana, may look the same on the shelf however they have different prices because the former is certified and comes at a higher cost. The production processes of the cocoa beans are different. Whilst Divine accounts for environmental sustainability, Golden Tree may not. In the same vein product markets are also not perfect, and come with its inherent price differentials.

With the given problems above, how then do we empirically measure the contributions of these inputs to productivity? A number of ways have been suggested by different authors, depending on the situation in which one finds himself/herself. In measuring Capital (investment) - labour ratio, Stewart (1977) calculates K/L as acquisition cost divided by man-days for block manufacture in Kenya. In an attempt to make allowance for different asset lives, acquisition costs are converted into annual investment cost using the equation;

$$PV = \frac{A}{r}\left(1 - \frac{1}{(1+r)^n}\right) \quad (3.1)$$ [8]

Thus annual investment cost can be expressed as;

$$= rPV/(1 - \frac{1}{(1+r)^n}) \quad (3.2)$$

[8] *Where A constant annual cash flow; PV is present value of the cash flow which is equal to initial acquisitions cost; r=interest rate; and n=number of years*

Labour productivity (O/L) has also been measured in an empirical study in the bread making industry in Kenya by Kaplinsky (1990). Here, labour was measured in a way similar to Stewart's method. The main assumption is that labour in the bread industry is largely unskilled and fairly homogenous in that respect; but the point is if over time some of them become skilled through formal training, then some weight must be applied to account for the training. Efforts in measuring output is relatively difficult because firms produce different mixes of bread and confessionary. Therefore based on observed differences in time and other inputs, the output of the firms is converted to ordinary-bread equivalents. Thus, for example, O/L will be equal 4000 loaves per year for a technique that employs 30 workers and produces 120,000 loaf equivalents in a year. Capital productivity (O/K) has also been done in the Kaplinsky's (1990) example of bread industry. Capital was measured in a slightly different way from Stewart (1975). Stewart used annualised acquisition cost while Kaplinsky used annualised replacement cost based on economic life of the equipment. With already measured output, O/L is calculated by dividing the output by the value of annual investment (either calculated by Kaplinsky's or Stewart's approach).

3.7 Technology transfer and diffusion

Underdeveloped countries are at a huge disadvantage in the global high tech economy. Until recent changes in China and India, underdeveloped countries had fallen behind the developed world in both acquired and domestically developed technologies. There are two main ways through which nations and firms can acquire technologies: produce their own or procure from other nations or firms. Thus one of the ways to bridge the technological gap is to enhance the international transfer of technologies. The importance of international technology transfer for economic development can hardly be overstated. A fundamental process that influences the economic performance of nations and firms is technology transfer (Mansfield, et al., 1982). Both the acquisition of technology and its diffusion foster productivity growth (Hoekman, Maskus, & Saggi, 2004).

Technology transfer has been described as an intersection between business, science, engineering, law and government. The process by which a party in one country gains access to, and absorbs technical information into their own production process from a foreign party is referred to as international technology transfer. International technology transfer has the potential to encourage economic growth, and some writers have argued that the gap between incomes of developed and developing countries can be explained by the barriers to technology adoption that exists between the two worlds.

The foundations of international technology transfer is built upon the exchange of information and knowledge (Tassey, 1992) which maybe codified or uncodified; embodied in products or people; or disembodied in ideas or people. Technology transfer can be a market-based transaction between unrelated parties or through a non-market mediated approach (Kim, 1991). When the technology transfer is market mediated, the seller and buyer are able to negotiate the cost of the technology using market mechanisms. These market-based technology transfer mechanisms may come in the form of FDI, foreign licensing, technological consultancy, made-to-order technologies and standard machinery or capital goods purchase. The non-market channels of technology transfer also take place without a formal agreement between the two parties. They come in the form of technical assistance by foreign buyer or vendor, and the supplier takes an active role in the process. The supplier in non-market mediation may also take a passive role when the transfer process occurs through imitation, observation, trade journals or technical information service.

Another classification of technology transfer puts the channels into two broad categories, public and private (Van Tho, 1993). When the public is the main driver of technology transfer, the technology so transferred can be considered as a public good. For example governments of developed countries or development agencies may facilitate the transfer of technologies with the view to providing assistance (aid) to a developing country. In the case of private channels, it consists of technologies that have been developed by the private firms and transferred on a commercial basis. Multinational corporations are the main suppliers using this channel and they employ FDI, licensing agreements, plant export (capital goods) and original equipment manufacturing.

In the framework of this study, the main kinds of technologies being considered are power tillers and tractors exported as capital goods either through markets or non-market channels as delineated by Kim (1991) or through public or private channels as sketched by (Van Tho, 1993). The import of capital goods and machinery is among the major modes of technology transfer for building industrial infrastructure and strengthening the recipient country's technological capability (Jafarieh, 2001). This channel of technology transfer, which was used by many developing countries in East Asia, assisted these countries in accessing the advanced technologies embodied in the machinery and equipment. However, the success of this method of technology transfer in the development of the recipient country's local technological capability relies on the level of industrial development (infrastructure) together with the degree of technical and managerial expertise and its absorptive capacity (Mowery & Oxley, 1995).

Cohen & Levinthal, (1990) defined absorptive capacity as the ability of a firm to recognise the value of new external information, assimilate it and apply it to commercial ends. It focuses on the firms' ability to sense their information environment, to recognise new technological opportunities and to capture and integrate new information and knowledge into the firms' processes and routines with the subsequent aim and result of increased competitive advantage (Lane et al., 2001). In fact, for the three pillars of absorptive capacity in relation to mechanisation, it is abundantly clear that Tanzania recognises the importance of the new knowledge embedded in tillage capital goods by embarking on policies which seeks to make power tillers and tractors available to farmers (Mmari & Mpanduji, 2014). However, whether the country can assimilate and use them for a commercial gain depends on market and managerial infrastructure requisite for technology transfer and diffusion.

Important questions to be asked here are whether market players have the requisite knowledge, competence and financial resources to facilitate the international transfer of capital goods in a manner that benefit the rural poor farmer. Paucity of infrastructure comes to bear. For instance importers of tractors and power tillers may have the intention of importing tillage technologies for diffusion locally. However their ability to source the requisite financial services, identify reliable and trustworthy suppliers are all crucial. When the machines have finally arrived in the country, what forms of dealership infrastructure exists to support their diffusion? Transport infrastructure as well as ware housing are both key. To provide after sales service, the technical knowhow and skill requirements cannot be overlooked. Creation of linkages between importers, local dealers and users as well as financial institutions are very important fundamentals that enhance the importation and distribution of capital goods. On the part of users, knowing how to operate the machines is critical for it to last its economic life and also provide the requisite benefits.

When Mmari & Mpanduji (2014) studied the diffusion of power tillers in the Mbarali and Kolombero Districts of Tanzania, they found that generally the factors which enhances farmers' ability to assimilate the technologies were lacking. At the time of introduction of power tillers, very little knowhow existed on the use and maintenance of power tillers, neither at the Ministry and other institutions or the farmers or operators of power tillers. In addition, competent power tiller operators who are required to make the technology useful to farmers were also lacking because of the absence of requisite training. Most of the operators had an informal training through learning by doing from another operator who might have also been trained through trial and error. In some situations spare parts markets functioned poorly and users had to travel up to 80km to find the spare parts. The study concludes that there were design limitations in the technologies transferred, institutional limitations (market failure) and the need to scale up trainingg for users.

Again the mere fact that developing countries lag behind in technology generation suggests that there is opportunity for technologies to be transferred from abroad through an international technology transfer approach. The use of the word 'transfer' in the international technology transfer concept may suggest that it is a smooth and automatic process without barriers. In reality, for international technology transfer to occur, providers of technology and acquirers must deliberately invest in the process. It is a more complex iterative process (Edquist & Jacobsson, 1988). Aside from this investment constraint, international technology transfer may be undermined by market failures embedded in the presence of asymmetric information or market power (Jafarieh, 2001). Market transactions in technologies could also be hampered by externalities (Hoekman et al., 2004).

Since technology transfer involves the exchange of information between those who have it and those who do not, the former cannot reveal all the information about the technology without destroying the basis of trade, and this result in asymmetric information problems. Buyers cannot determine the value of all the information given before procuring it. Technology leaders (firms receiving or leading the development of particular technologies) usually have significant amounts of market power. This might result in pricing of technologies above their socially optimal levels. The difference in pricing and actual cost may increase the profits of innovators, but social benefits are greatly sacrificed.

When costs and benefits associated with technologies are not fully internalised, externalities occur - they can be positive or negative. Because of these market failures, there is room for government policy to improve welfare. Even though in practice the potential for policy to improve welfare may not work because of mistakes or rent seeking behaviour, Hoekman, et al. (2004) suggest that for policy to be effective, it must alter the incentives of private agents that possess innovative technologies. For government to know the right incentive to pursue an understanding of the loopholes in the system is required and this needs localised forms of research which this thesis hopes to contribute to.

3.8 Conclusion

SSA governments, international development organisations and farmers on the continent remain puzzled about why for several decades mechanisation of farms on other continents has occurred smoothly whilst in their own backyard, several attempts have failed. This challenge could lie in the fact that for so long a time, the limited scope of efficient technologies were mainly developed in, and tailored for advanced country conditions. China and India's rise on the globe could potentially change the status quo. Technologies suitable for developing world conditions are being generated by China and India. This new development presents new opportunities for a change, but they can only be harnessed if there is an in depth understanding of how an appropriate choice is made in the context of abundant labour supply, limited skills and capital constraints as is in the case of Tanzania.

To make an optimal choice under developing country conditions, it must be recognised that not all technically efficient technologies are economically efficient because of differences in factor prices within different economies. Some economically efficient technologies may also not be feasible because of engineering limitations in the real world. To ensure that technologies are optimal, the scale of operation, quality of output in relation to the size of markets and characteristics of consumers must be given adequate attention. Since Tanzanian farmers are generally low income earners and operate relatively smaller farms, choices made should address these peculiar limitations, and it might be that Chinese and Indian Technologies may provide these options which the developed world ones have not met fully in the past. The environment, health and employment concerns of users must also be kept in the balance as we consider technological change, to ensure that whilst we hope to satisfy the requirements of limited financial resources, other aspects of the production environment are also protected.

Technological change is socially constructed. Thus factor endowments of the society and what societies believe in may shape the dominant technologies so developed. Since China and India are in themselves developing, their own circumstances which may be similar to other developing countries are likely to shape their technologies. Thus tillage technologies coming from these two emerging economies are worth considering by Tanzanian farmers. To make them accessible technology transfer and diffusion is key. However, because of market imperfections, not all externalities generated through the technology transfer process are internalised by the agents responsible. This may call for government regulations which must be kept in a balance if the right incentives are to be created for markets to adjust positively. Beyond market imperfections, there could be challenges with user absorptive capacity for the technologies transferred. To improve absorptive capacity, training for users is crucial. In the following Chapters, we shall attempt to establish whether emerging economy tillage technologies are profitable and if they are in the first instance and in the second whether they are worthwhile choice for the poor farmer in Tanzania.

Chapter 4 : Methodology

4.1 Introduction

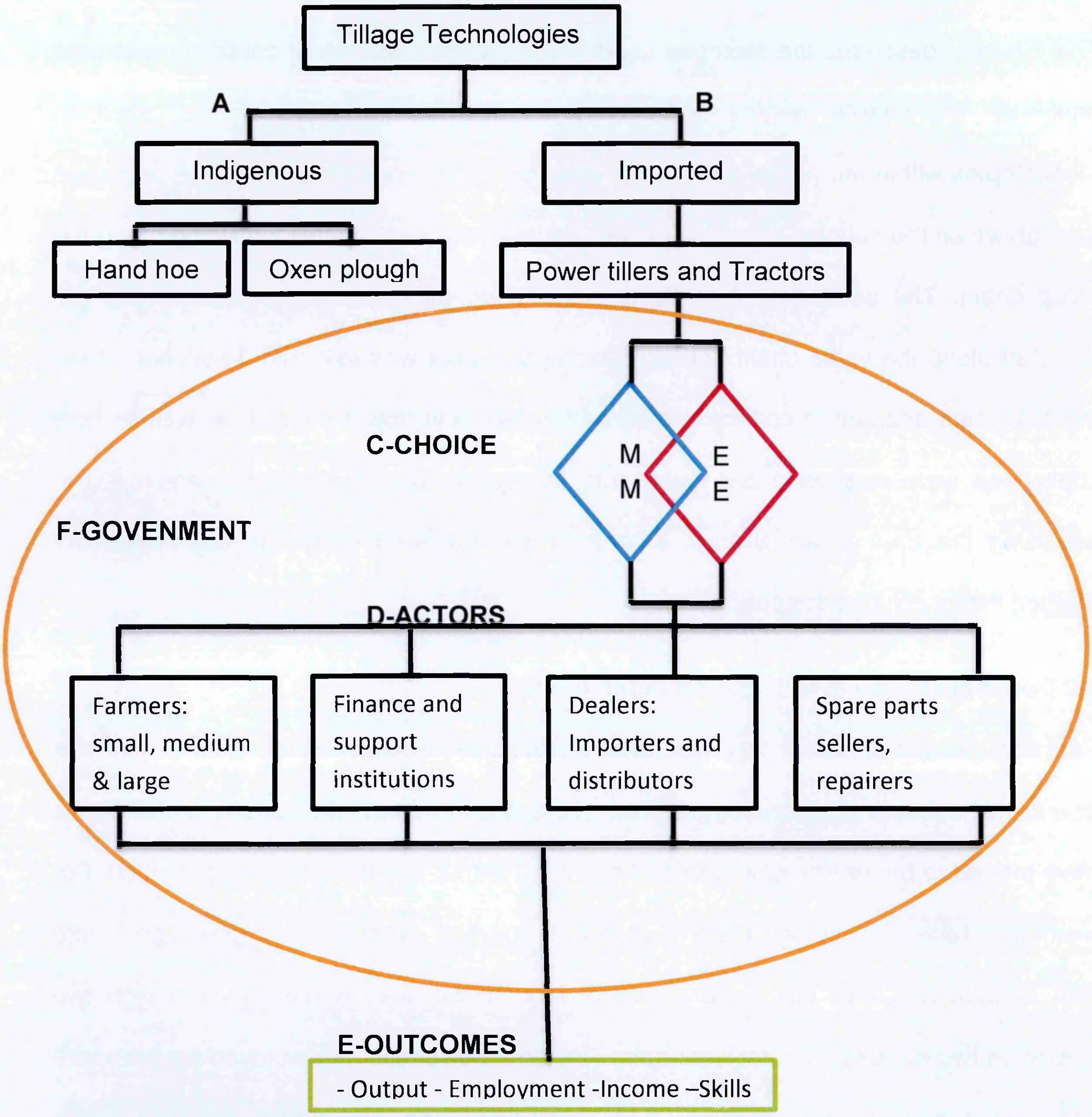
This Chapter describes the methods used in sample selection, data collection and data analyses. The chapter begins by defining the alternative choices of mechanisation technologies within the agricultural sector used by Tanzanian farmers and the pathways through which their choice influence growth, productivity and capability building along the value chain. The second section describes the sampling procedure and the sample selected along the value chain and why each participant was selected. In section three, the strategies adopted in collecting data on the field and how it evolved as well as how challenges were dealt with are discussed. In section four, the methods employed in analysing the data in an attempt to answer the research questions are presented. Section five concludes the chapter.

4.2 Conceptual framework and research design

Farmers can either invest in indigenous technologies (hand hoe or oxen plough) or invest in mechanized technology (power tillers and tractors). Indigenous technologies have proved to be *inefficient* in terms of quality of output and timeliness of operation. For example it takes an average man 12 days of 5 hours of intensive work to plough 1 acre with a hand hoe. For the same parcel of land, it will take a pair of oxen with two operators two days of 5 hours' work each. When a power tiller is employed for the same assignment, it takes an average of 3.5 hours with one man. The average tractor ploughs an acre within an hour with one operator (Key informant Interview, 2012). The quality and quantity of output per labour hour, all things being equal, improves as one move from hand hoe, through oxen to tractors. In an instance where the soil structure is undulating as it occurs in mountainous areas, it becomes impractical to use oxen or tractors: hand hoes or zero tillage becomes ideal.

If soil structure were conducive, then the *'progressive'* farmer might naturally move from the use of hand hoes and oxen ploughs to the use of power tillers and tractors for tillage.

Figure 4.1: Conceptual framework



Source: Author, 2013

Limiting factors to the ownership or use of power tillers and tractors may include finance and availability of a reliable supply chain, skill requirements, technological complexities and the scale of operation of the user. Users thus consider these limitations in making decisions about technology choice. Under our present considerations therefore, each farmer can choose a power tiller or tractor from a Mature Economy (MM) or Emerging Economy (EE) source, assuming that with the present objective of improving productivity, hand hoe and oxen ploughs are not promising enough.

Choosing an MM or EE machine will have varying implications on employment, output, incomes and capability building of actors in the value chain[9]. That is if the two sources of technologies have different characteristics, then these differences are likely to impact differently on participants in the value chain. Figure 4.1 is a diagram showing the main types of tillage technologies available to the Tanzanian farmer. Route **A** on the diagram represents indigenous technologies which are excluded in the analyses in this thesis. The study concentrates on Route **B.** Under Route **B,** there is a choice **C,** to be made between tractors and power tillers with MM or EE origins. There are also actors, **D** comprising of users (farmers and operators), financial institutions, dealers and service providers. Finally, there is government **F,** which also participate in the system. Each of the actors in the system plays a different role and these roles, depending on the choice affects the outcomes, **E.**

Dealers as actors in this technology system are responsible for the importation of the technologies and distribution within the country to sales agents and sometimes directly to farmers. The machines they import are dictated by what manufacturers have on offer, signals from users and their own financial situation. The dealers may borrow from financial institutions to finance the imports and so they also collaborate with the banks. Farmers (users) buy the imported machines and use them on their farms for tillage. They sometimes borrow to finance their investments and so are highly reliant on financial institutions for such purchases. Some farmers, usually large scale ones, buy their own tractors from abroad, without the help of importers. The service providers like repairers and spare parts sellers also work in close collaboration with users and dealers. They provide parts for replacement and also provide regular maintenance and repair when machines break down. Some spare part sellers also depend on financial institutions for capital for their business. All these actors operate in a policy framework defined by

[9] In the same vein the intersection of MM and EE which represents machines which combine characteristics of the two sources will also have varying impacts on output, income, employment and skills.

government. The government among other things makes decisions on tax and subsidies and is also supposed to inspect machines to ensure that they meet the quality standards as specified by the laws of the country through testing. Education, training and expertise building through extension activities and traditional schools is also supposed to be led by government.

4.3 Sampling and data considerations

Four main types of data sets were collected: survey data from farmers owning power tillers and tractors; market structure data from key informants (farmers, dealers, financial institutions and government officials - local, regional and national); operational performance data from machine operators, repairers, educational and testing institutions and through physical observations while machines are in use; and secondary data through desk review of documents related to the sector. This study used the hybrid or mixed methods approach, combining the traditions of different ways of doing research in designing the field work. That is both qualitative and quantitative methods were employed in data collection. The objective of this approach was to ensure that data collected from one source could be corroborated or triangulated with other sources through more than just one means. We discuss these methods in turn and present some of the precautions taken to ensure rigour, credibility, validity and reliability of the data collected.

a. Flexible research design approaches and qualitative data

Qualitative studies vary by type, purpose and quality. Qualitative study findings can either grow out of an in-depth or open-ended interviews; direct observation; and written documents. Through interviews, direct quotations of people about their experiences, opinions, feelings and knowledge can be generated. Open-ended questions and probes yield in-depth responses, and the data generated consists of verbatim quotations with sufficient context to be interpreted. Data from observations are made up of descriptions of activities, behaviours, actions and processes that are part of their experiences which can be seen. Here the data consists of field notes which are rich, detailed descriptions, including the context within which the observations were made. To analyse documents, studies of expert quotations or entire passages from various forms of records, correspondence, official publications, reports, dairies and open-ended responses to questionnaires and surveys are required. (Patton, 2002).

b. Fixed designs for quantitative data

These are theory driven research designs in which the phenomena of interest are usually quantified. The concept of variables is important. Fixed designs require that variables to be included in the study must be specified in advance. There should be a conceptual understanding about how one variable drives the other. This understanding may be in the form of a model. This suggests that the mechanisms that are likely to be in operation are clearly understood by the researcher. Fixed designs are usually piloted before the main phase of the study. This is important to ensure that the phenomena being studied have been captured sufficiently well for meaningful data to be collected. Fixed design rely heavily on measures of central tendencies (averages) and so the larger the sample the better. There are several strategies which can be adopted for fixed designs. One of such methods is the survey where enumerators are used for the administration of structured are semi structured instruments. Enumerator bias could affect the validity and reliability of the data. This challenge requires that data collectors are given thorough training beforehand. (See Robson, 1994).

c. Trustworthiness, validity and reliability of data of qualitative data

Though the trustworthiness or otherwise of findings from flexible, qualitative research is a subject of much debate (Robson, 2002), if the same research cannot not be replicated using a similar methodology to obtain consistent results, then it casts doubt on the level of acceptability of whatever recommendations are made. However, whilst the standard practice for the natural sciences to test validity of a finding is for it to be replicated by an independent scientist, this approach may not be feasible when a flexible qualitative research procedure is used. Whilst some social scientists accept that the predictive power of qualitative methods is limited because societal characteristics cannot be held constant (Bloor, 1997) and some do not believe that the tenets of scientific enquiry are significant (Guba and Lincoln, 1989). Maxwell (1992) notes that some of the threats to the validity of flexible designs could be captured under three areas: description; interpretation; and theory. First the main challenge in describing what you have heard lies in the inaccuracy or incompleteness of the data. The writer suggests that where possible, taping of conversation should be carried out. Threats to valid interpretation occur when the researcher attempts to impose a framework on the meaning of what is happening rather than allowing the framework to emerge from the setting. If one gets stuck in a particular theory and does not attempt to seek alternative explanations for understanding of the phenomena they are studying, it can become a threat to validity.

Robson (2002) suggests a number of general skills needed for flexible qualitative research in an attempt to improve the validity of the data so collected, and these were heavily relied upon during the field work. First, he suggests an enquiring mind that is prepared to ask questions at all times during the field work. This may be mentally and emotionally exhausting, but it is the only way to know why events are happening the way they do. Second, good listening is also required. The main tenet of good listening is that the researcher is prepared to take in a lot of information without bias and noting down exactly what was said. If possible, the mood can be an effective component that will help capture the context. Simply put, the data collector must have an open mind. Third, because such field studies do not always end the way planned, the researcher must be adaptive and flexible. That is you have to be willing to change, and the implications of any change must be taken on board. Some of these changes can have consequences for research design. Fourth, the fact that the investigator needs to interpret data means that the issues must be grasped and not just recorded. Without a firm grasps of issues, clues, contradictions and requirements for further evidence may be missed. Fifth, all the above skills become futile if the researcher is biased and has a pre-conceived position. Investigators should be open to contrary findings. These tools were always at the back of my mind especially during observations, interviews and review of documents in the hope that trustworthiness of what I find will be upheld.

4.3.1 Institutional survey protocol for market structure and key informants

The main institutions targeted were government (Ministry of Agriculture, Ministry of Trade-Border Agencies (customs) and Science and Technology Institutions), non-government (religious, international and farmer groups) and private businesses (importers, distributors and service providers). The objective of speaking with the government institutions was to gain an understanding of government policy, the role that government is playing at each level of the supply chain (technology transfer from abroad and diffusion within country) and the challenges being faced. The NGOs, especially the cooperatives, are also very important in the agricultural marketing and finance chain in Tanzania, and so understanding the resources they have and how they were being used to facilitate farmer access of technologies was key to the study. Finally, the private businesses which are involved in the importation, distribution, service and finance had a lot to say about the diffusion process including their sources of supply and the inducements to what they bring in for sale.

Key informants at the government departments were contacted and interviewed to throw some light on what is being done generally and what government in particular is doing in connection with mechanisation, technology transfer and diffusion. Through these interviews some of the main institutions participating in the sourcing and distribution of power tillers and tractors were identified and interviewed. The identification process was also supported with desk reviews of country reports. Finally, the private businesses were contacted through a list produced by the Agricultural Mechanisation Department of the

Ministry of Agriculture, Food and Cooperatives. Other businesses which were not on this list were also brought into the frame through snowballing strategy. Since most of the importers are based in Dar es Salaam, it was the starting base and I then moved to other centres where they were found as per the information obtained from other importers and distributors. Room was made for proportional representation of MM and EE capital goods, to facilitate the comparative approach of the study.

Table 4.1: Key informant interviews by region and by type of informant (count)

	Region									
Type of key informant interviews and surveys	**Morogoro**	**Iringa**	**Mbeya**	**Manyera**	**Dodoma**	**Mwanza**	**Dar**	**Arusha**	**Moshi**	
District executives	1	2	2	1	2		5		2	15
Mechanisation officer	5	1	2	1	1		4		1	15
Extension officer	5	6	2	3	2	1				19
Research scientist	4			1			1	3	3	12
Mechanisation tutors	1								1	2
Mechanisation students	2									2
Managers of schools	2								2	4
Large scale farmers	2		3							5
Mechanics/fabricators/engineers	8				4	2			1	15
Importers/dealers	7		4		1			3	2	17
Operators (drivers)	7	2	3	2	3					17
Financial Institutions/cooperatives	7	1	1		4		1			14
Total	**51**	**12**	**17**	**8**	**17**	**3**	**11**	**6**	**12**	**137**

Source: Author's compilation, 2012/2014

4.3.2 Farm survey and protocol used

Based on discussions with mechanisation officers at the national, regional and district offices of the Ministry of Agriculture, Food Security and Cooperatives, and with the help of key informants at the village level, 12 communities were selected from five of the 30 regions in Tanzania (Wilson, 2005). These five regions were purposively selected for the study based on factors that were anticipated to possess the potential for examination of particular environmental and institutional influences on technology transfer and diffusion after a literature survey.

Manyera (Babati) the first of the five regions selected is home to a substantial proportion of all tractors in Tanzania, according to the Agricultural Sample Census 2007. It was selected to give room for comparing various ranges of power tillers and tractors across farms of different scale of operation and examination of the extent of use. In this region also, there are two distinct growing seasons as a result of a bi-modal rainfall regime and this could also affect the annual profitability of machinery use. It was anticipated that this region could throw more light on resource endowment and choice of technology.

The second region selected, Dodoma, is characteristic of relatively drier but lighter soils which may allow the use of smaller tractors in terms of horsepower. As the new administrative capital of Tanzania, a lot of institutions including NGOs supporting agriculture and financial institutions are springing up in the region and this gives room for understanding institutional role in the mechanisms of technology transfer and how their presence or otherwise influences technological choice. There has also been a long presence of Indian tractors in the region, and this was of particular interest to the study.

Morogoro, the third region selected for the study, by contrast has heavy, water-logged and clayey soils which may require more robust machines with larger horsepower for tillage. The nature of the soil is a characteristic which could have influenced the path for the types of technology selected. Thus it offered the opportunity to study the tillage equipment under irrigated conditions. In addition, the presence of large scale sugarcane and rice farms meant that the study could also examine the choice of technique by commercial farms.

Mbeya was selected as the fourth region for field studies because it has the highest population of power tillers in the country (20% of the total) and small paddy fields were common on irrigation schemes. This character of the region facilitated the comparison of various types of power tillers. This was because for most of the irrigation schemes, there was a critical mass of power tillers with similar vintages. Co-operative society support for machinery procurement was also popular, and this dynamic was important to understand since the issue of funding is very crucial for mechanisation.

Last is the Iringa region. The purpose for choosing this region was to examine how the choice of technique has been influenced by the origin of foreign investors in commercial farming. Europeans, especially Greek and German farmers, cultivate large tracts of land in this region, and it was interesting to find out whether those who bring in FDI also bring in technologies from their own countries.

In each region, the most important district, in terms of mechanisation was chosen, with the help of the District Mechanisation Officer. In situations where this criterion was impossible because more than one district qualified as the most important in terms of number of tractors and power tillers, the district which is closest to the regional capital was chosen. The idea behind this strategy was that in the broader scheme of things, data collection was going to happen in both the regional capital and the district in question, and so the closer they are, the better for logistical limitations. Within the district a similar strategy was used for the selection of communities with a little modification.

First, communities selected should be an important mechanisation area. Whilst towns or villages closer to the district capital were desirable for easy access, the study also wanted to determine whether more rural farms had different technology choice trajectory compared to those closer to urban centres. Thus at least one of the communities selected was closer to a main road, while the other was not. For almost all the towns considered here, institutional memory of extension officers and other key informants as well as a register of farmers owning tractors and power tillers obtained from the district office were used in the decision making (Burgess, 1984; Wilson, 2005). Using the register to locate a few farmers at the onset, the remaining farmers were reached through a snowball approach (Coleman, 1958).

In total, 194 farms which owned at least one power tiller or tractor were drawn from the communities for the study. From the Dodoma region, two communities (Hembahemba and Ngomai) were selected and the sample drawn from here constitute over one fifth of the total. From the *Iringa* region where a little below one fifth of the total sample was drawn, three communities consisting of Ilula, Nzihi and Pawaga were considered.

Gallapo and Magugu were the two communities selected from the Babati region and in total, farms considered from these two communities constituted about 15% of the total sample. A little over one third of the total sample was drawn from the *Mbeya* region where Mabadaga, Mbuyuni and Ubaruku were the communities of interest. Of this proportion more than half came from the Ubaruku village where close to one third of all the power tillers in the district are located. The last region, Morogoro, provided two research sites, Dakawa and Turiani which together served as a source of more than one tenth of the total sample.

The original target was that at least for each region, 60 farmers should be interviewed- so that the total sample would comprise 300: a figure which could allow for statistical tests of means. At the end of the data collection exercise, 225 farmer surveys were completed. Of these 225, 194 were in a form that was good enough for the purposes of this study. The surveys discarded were either incomplete or the respondents had not used their machines to a significant extent in the season under review. There were others where the responses deviated from believable averages as triangulated from extension officers. Some of them were also answered by caretakers of the machines and so did not have full insights about the data we intended to collect. Table 4.2 shows the distribution of farmers surveyed and used in the analyses in this study by region, district and community.

Table 4.2: Regions, communities and samples drawn

Region name	District name	Frequency (%)	Community name	Frequency (%)	Regional population of (...), 2011	
					Power Tillers	Tractors
Dodoma	Kongua	44(22.8)	Hembahemba	36 (18.6)		
			Ngomai	8 (4.1)	215	781
Iringa	Iringa rural	36(18.7)	Ilula	9 (4.6)		
			Nzihi	7 (3.6)		
			Pawaga	20 (10.3)	477	306
Manyera	Babati	29(15.0)	Gallapo	14 (7.2)		
			Magugu	15 (7.7)	186	1092
Mbeya	Mbarali	64(33.2)	Mabadaga	18 (9.3)		
			Mbuyuni	10 (5.2)		
			Ubaruku	36 (18.6)	1073	405
Morogoro	Invomero	20(10.3)	Dakawa	8 (4.1)		
			Turiani	12 (6.2)	327	1134
Sample				**194**	**2278**	**3718**
National					**4571**	**8466**

Source: Field Work, 2012/2013; Ministry of Agriculture, Food Security and Cooperatives, 2011

4.3.3 Operational and performance data

The main source of data for how well different technologies perform on different terrains were obtained from power tiller and tractor operators, mechanics, educational institutions and machine testing units. In identifying operators and mechanics for in-depth interviews, farmers participating in the surveys were asked to direct me to the operator and mechanics they used during the season. As many operators as possible who were available and accessible at the time of the data collection were contacted for interviews. There was also a direct attempt made to interview equal proportions of operators of MM and EE machines where possible. In most of the communities visited, there were a handful of repairers and all those available at the time of the data collection exercise, were interviewed (usually an average of 4).

In addition, a focus group discussion with operators who have had the opportunity to use both MM and EE machines was carried out in one of the communities. To get an understanding of the gender effects on choice, another focus group discussion was also carried out with women owning power tillers. Two of the educational institutions mandated to train experts and farmers in using and maintaining farm machinery were contacted: the Morogoro Agro-Mechanisation Institute and Moshi Irrigation Development Scheme. Students, farmers under training and instructors in the two institutes were interviewed - there were also field observations in the training centres as the two types of machines performed duties. Other field observations were undertaken on farms which were not related to the training institutes. In selecting these farms, farmers who had been surveyed and agreed to allow me to accompany them to their fields were targeted.

4.3.4 Sector overview data

Data on the national and regional distribution of power tillers and tractors and the history on how the sector has evolved were obtained from secondary sources. These sources included reports by government institutions, especially those generated by the Ministry of Food, Agriculture and Cooperatives of Tanzania. Others were obtained from the review of literature as well as key informant interviews with staff of the Mechanisation Department.

4.4 Data collection process

The data collection exercise spanned a period of 7 months with a total of 29 different research assistants involved during the process. There was however one main assistant who was involved from the beginning to the end of the process. Survey instruments (questionnaires, cognitive specimens, check lists and key words) for the study were first translated from English to Swahili in the first week of August. Before pre-testing the questionnaires in the second week, I had the opportunity to attend two national agricultural shows. There was also a seminar organized by the Economics Department of the Mzumbe University for experts in the industry to comment on the methodology proposed for the study. Outcomes of these two separate activities were used to modify the data collection instruments.

The questionnaires were then pre-tested in the second week of August, 2012 at Dakawa in the Invomero District of the Morogoro Region. After the pre-test, data was entered into a spread sheet; an evaluation with the research assistant revealed questions which were not answered properly or were not properly understood by farmers, dealers, operators, mechanics or government officials. The instruments were thus reviewed for improvement. With the survey instruments ready and the necessary contacts obtained in the different regions proposed for data collection, the exercise begun in Mbeya in September 2012 and ended in Mwanza in February 2013. There were however intermittent trips to Dar es Salaam to speak with key informants in the value chain whenever they agreed for an interview.

In each of the communities, the mechanisation officer at the district office and the village executive officers helped in identifying prospective data collectors who were then trained with the help of my main research assistant. These data collectors were mainly responsible for interviewing farmers who owned power tillers or tractors. Whilst this exercise went on, the research assistant and I carried out the institutional data collection part of the process. Concurrently, we also supervised the survey and provided explanation and clarifications to data collectors on issues that were confusing. The surveyed questionnaires were reviewed by me, and where necessary the data collector revisited the farmer for further questioning. Most often, I sat in the first 1 or 2 surveys conducted by an enumerator to ensure that they understood what they had been asked to do. Where there were misunderstandings, we regrouped and explained things again before further interviews were done.

As the data collection exercise moved from one region to the next and my understanding of the industry improved some questions were modified greatly or removed entirely if their contribution to the research was not great. The data sets that these field interviews and surveys collected, and the research questions they addressed are captured in Table 4.3 below.

4.5 Data analyses

The main analytical tools for the study were simple means, percentages and ratios that identify differences and distinctiveness between MM and EE mechanisation technologies. Statistical tests like the *t*-test were also used in some instances to test the significance of the differences observed. Other qualitative analyses based on narratives and observations were also undertaken. Further empirical computations of input and output co-efficient were generated. Qualitative data collected from focus groups and key informants were organized, transcribed and sorted under various themes ranging from policy, technology diffusion channels, motivations of choice and services along the channels. The themes generated and the text thereof is presented under the four research questions outlined in Chapter 1 (page 8) with the objective of comparing the findings with what theory and historical evidence suggests.

4.5.1 Research question 1

What is the mode of transfer and diffusion of MM and EE tillage technology in Tanzania?

In addressing the question of the transfer and diffusion mode, a historical view is taken. Thus policies, activities, sources of supply and quantities imported at the national level since Tanzania became a republic are discussed. The discussions on tractors are divided into the pre-Structural Adjustment and post-Structural Adjustment periods. The market fundamentals for the two time periods were very different and affected technical choice in different ways. The power tiller transfer and diffusion story is also told with a pre-2005 and a post-2005 view. The period before 2005 was dominated by MM power tillers. Post-2005 saw a market dominated by EE power tillers and the idea is to study the factors that influenced this change. The numbers used in this section to compare diffusion are presented using mainly bar charts.

In studying the mode of diffusion, major participants in the value chain form the matrix for the discussion. Foreign investors, traders, government and NGOs as participants in the value chain are evaluated with the view of showing the ways in which they transfer and diffuse tractors and power tillers in Tanzania.

4.5.2 Research question 2

To what extent are MM and EE tillage capital goods being used in Tanzania?

The extent of use of MM and EE power tillers are studied at two levels. First within the sample a comparison of the frequencies of MM and EE is undertaken. On farms, proportions of MM and EE owners using their machines for various farm operations are also compared. In both instances, percentages are used to make the differences clearer and presented pictorially with bar charts.

4.5.3 Research question 3

In what ways are MM tillage technologies distinctive from EE ones?

The distinctive nature of MM and EE power tillers are discussed using both qualitative and quantitative data. Age, lifespan and horsepower are presented and compared using averages of data reported by users within the sample. Other characteristics pertaining to satisfaction of users are ranked and an average of these ranks is presented with their significance levels.

4.5.4 Research question 4

Do the inherent distinctive characteristics thereof, (if any), of EE tillage technologies help address the needs of resource constrained farmers and other participants in the value chain and hence reduce poverty?

The economic appropriateness is based on the analysis of the coefficients of production and hence required the measurement of output per season, labour employed and capital costs. Averages for these measurements are presented for power tillers and tractors within sub-groups of MM and EE machines. The economic discussion ends with computations of efficiency ratios and benefit-cost estimations. The benefit-cost discussions are enriched with sensitivity analyses, mainly based on a realistic scenario of government subsidies on farm machinery being removed in future. The social appropriateness discusses which technologies get diffused by ranking and comparing the physical ratios, benefit-costs and level of diffusion. Simulations are also carried out to find the impact of choosing each of the technologies on employment impact and skills.

In general, this thesis assumes that output (measured in number of acres[10] of land ploughed) is generally homogeneous in terms of the quality of ploughing, harrowing or rotavation. To cater for the slight differences across machines an attempt is made to increase our sample size to as large as possible so that our measures of central tendency could be as accurate as possible. We measure labour as the person hours per acre of work done, and here again we hope that the large sample size adopted will give further confidence to the mean values generated. Capital is measured using both the acquisition and the replacement costs, following Stewart's method (see Chapter 3). Table 4.3 gives an overview of the kinds of data collected for each of the research questions and the methods adopted.

Table 4.3: Research questions and data needs

Research questions	**Data needs**	**Sampling approach**	**Data collection methods**
Transfer and diffusion mode	Open market, relational, sourcing from abroad,	Focus groups/ Snowballing	Focus group interviews targeting mainly qualitative, but also quantitative
Extent of use	Number imported; Incidence of use within sampled farms	Purposive random sampling/ Snowballing	Quantitative data using desk review, sampled farmers
Distinctive nature	Scale , Cost, Durability, Labour, Infrastructure, Efficiency, energy	Purposive random sampling/ Snowballing	Physical inspection, farm records, survey Instrument
Economic & social appropriateness	Farm and farmer features, environmental features	Purposive random sampling/ Snowballing	Survey instrument administered to sampled farmers

Source: Generated by author, 2013

[10] 2.47105 acres is equivalent to 1 hectare

4.6 Conclusion

This chapter presented the conceptual framework upon which this thesis is based. The methods that are used to collect and analyse the data collected to answer the research questions posed by the study were also discussed. A mixed method approach is adopted for the data analyses with the view of using different sources of data to triangulate and validate each of the answers provided for each research question by respondents. From the point of view of comparing matured market technologies with emerging economy ones, each technology is examined at the different levels of the value chain: importation; local diffusion; usage at the farm level; maintenance service provision; and financial support available to users and dealers. In Chapter 5, users and the capital goods available to them are classified and discussed.

Chapter 5 : Users and Capital Goods Classification

5.1 Introduction

The choice of tillage technology by Tanzanian farmers is constrained by technical requirements at the production level defined by soils, crops and farming systems. Their decisions are equally affected by economic requirements bounded by the social context and the labour supply in terms of quality and quantity. Availability of investment capital (amounts, cost and timeliness) is also a crucial determinant of choice. Output (nature, quantity and value) which has direct implications on farm profits and consequently resources available for financing purchases of capital goods is also key. Finally, access to and distribution of soft infrastructure such as repair and maintenance and a well-functioning spare parts market is important.

The influence of economic agents in the value chain (manufacturers, importers and distributors) as well as government policy and standard regimes shapes the supply side of tillage technologies to a large extent. An optimal technique choice (in the economic sense) means the maximization of the positive benefits presented by these factors whilst at the same time minimizing the negative risks and uncertainties they pose. Whilst social optimality is beyond the central scope of this study (since it is difficult to establish what is socially desirable for all agents), choice of technique in a broader scheme should also not turn a blind eye to social, cultural and environmental values embedded in inclusiveness, food security and sustainability objectives (Ruttan, 1959). We shall however, in Chapter 8, touch briefly on social optimality when we discuss the effects of technique choice in Tanzania on area cultivated, employment and skill development.

This Chapter seeks to define what an optimal choice of tillage technology is for small, medium and large scale farmers cultivating different crops under different agro-economic conditions. Thus, we first establish who our farmers are; what they do; how they do it; and what technology alternatives are available to them for these assignments. We discuss in turn the activities constituting farm mechanisation - that is, the nature and character of farming systems and the optimal types of equipment under those regimes. In addition, the Chapter specifically takes each of the regions under consideration and classifies them under farming systems. Here attention is paid to the common soil types in those regions and the crops grown. To understand the alternatives of technologies that exist for the farmer to choose from depending on his farm characteristics, a description and categorization of techniques is undertaken, first by their engineering attributes and then second, by the soil conditions which they are best suited.

Apart from engineering characteristics, we further categorize capital goods on the basis of their country of origin, which is the main subject matter of this study. We argue that there are two broad categories of technologies: advanced country and developing world. Under each of these two broad categories, there are two sub-divisions. That is, there are advanced country technologies which are produced in advanced countries and those produced in developing countries with the aim of taking advantage of competitive input prices or bringing production sites close to the market (Stewart, 1977) . For developing country technologies, there are those which have been developed locally and are produced locally and there are those which have been adapted from the advanced countries through collaborative work or outright purchase of intellectual property rights and also produced locally (Field work interviews, 2012).

With these classifications in mind, this Chapter sets up a matrix in the concluding section which then enables a discussion on the distinctive nature of technologies in Chapter 6, Chapter 7 and Chapter 8. The question of scale of operation is captured using the small walk-behind tillage equipment (power tillers) and large four-wheeled machines (tractors) dichotomy. The discussions are also undertaken in relation to farming systems, specific alternative brands of power tillers and tractors that may be suitable under these systems and the economic and productivity outcomes observed when they are selected.

The main concern in the discussions in this Chapter and those that follow is to establish the extent to which emerging economy power tillers and tractors are pro-poor in more ways than advanced country ones. With this concern in mind, we shall classify in Chapter 8, farm households as poor and non-poor using the basic needs poverty line[11] as a distinguishing criterion (Sarris, Savastano, & Christiaensen, 2006) when theoretical and policy implications are discussed. Benefits accruing to, and challenges faced by participants along the chain of technology transfer, diffusion and usage are also examined. In Section 5.2, we start off with a general overview of what constitutes farm mechanisation amongst the respondents under consideration.

5.2 Farm mechanisation

Agricultural productivity depends upon biological, hydrological, chemical and mechanical inputs. Contribution of mechanical inputs in farming is considered in terms of farm mechanisation. To optimize the use of biological, hydrological and chemical inputs, farm mechanisation plays a pivotal role (Yamin, Tahir, Nasir, & Yaseen, 2011). Essential for crop production in any system of agriculture, is how well the soil is prepared. Properly prepared soil serves as a reliable seed bed for sowing, germination and consequently supporting the gestation period of the crop. The soil or seed bed should be fine enough to hold adequate soil water, allow for air percolation and movement of soil micro-organisms. It should also allow for root and soil contact to an extent that water and nutrient absorption is high enough to facilitate proper plant growth and development. Beyond land preparation, are other field operations related to seeding, fertility management, plant protection, weed control and harvesting. There are also off-farm activities directly linked with what happens on the field such as transportation and processing of harvested products. This chain of on-farm and off-farm activities can also be mechanized totally, partially, or not at all (in the case of zero tillage).

[11] In rural areas where most farming households are located, the 2000/01 National Household Budget Survey suggests that 39.9 percent of all households fall under the basic needs poverty line, accounting for 81% of the poor in Tanzania (National Bureau of Statistics, 2002)

Regardless of the extent of mechanisation on a farm, a power unit is required. The three main farm power sources are human, animal and mechanical (Sims & Kienzle, 2006). Over time and space, farms may transit[12] from a pure human power based operations, through the introduction of animal power and then finally the use of mechanical power. Nevertheless, the choice amongst these three power sources will depend on availability of technologies in the first instance, technological know-how by the user, scale of operation and access to capital. The nature of the land also matters. For instance soils in hilly and mountainous areas may not support the use of animal power or tractors because of the steep slopes. Commercialization motivation of farmers could also influence the need to mechanize (Dixon, Gulliver, & Gibbon, 2001)

Human power on the farm is harnessed through the use of hand hoes and machetes. Machetes are used for weeding and holing. Hoes can be used for weeding, ploughing, mounding and ridging. Off-farm activities carried out by human beings include carting of farm produce usually on the head to the home or market, de-husking, shelling and grinding using simple tools or bare hands. Animal power is harnessed through the use of yokes that are hinged with simple implements. For transportation purposes, carts are yoked to the animals or saddles built on their back to carry loads tied firmly on the saddle (Rampokanyo, 2012). On the other hand, mechanical power produced by power tillers and tractors is transferred from the engine through power take-offs which are connected to drawbars for onward transmission to implements designed for farm work. For transportation purposes, the tractor is fitted with a trailer. Special equipment designed to draw power from stationary tractors, come in handy for postharvest handling. In capital constrained developing countries such as Tanzania, farmers rarely use the power tillers for tine cultivation/chiselling, agro-chemical application, weeding and post –harvest activities like de-husking, shelling and grinding (Field work interviews, 2012). Land preparation is by far the most important farm activity demanding mechanical power

[12] This transition is likely to occur in instances where soil structure support the use of animal and mechanical power- the availability of these technologies to the user is also key

because of the high energy requirements and the timeliness of operation, especially under rain-fed agriculture. As we shall see in the next Section, the soils, capital goods and farming systems are key considerations for land preparation.

5.3 Soils, capital goods and farming systems

Crops and the soils on which they are planted influence farm operations adopted, especially in relation to land preparation. Different crops can only be supported by particular types of soils and water supply regimes. Texture and structure of the soil has telling implications on the tillage operations carried out on the farm. The crop, and the planting methods adopted (broadcasting or precision seeding) will also inform the land preparation procedure followed. The interplay of the soil and crops consequently affect the kinds of capital goods (power tillers and tractors) required to accomplish each farm operation. Each type of capital good is inherently different and performs farming operations with differing engineering characteristics. In the same vein different farming systems require power tillers or tractors of varying scale, engineering technology and quality (strength and efficiency).

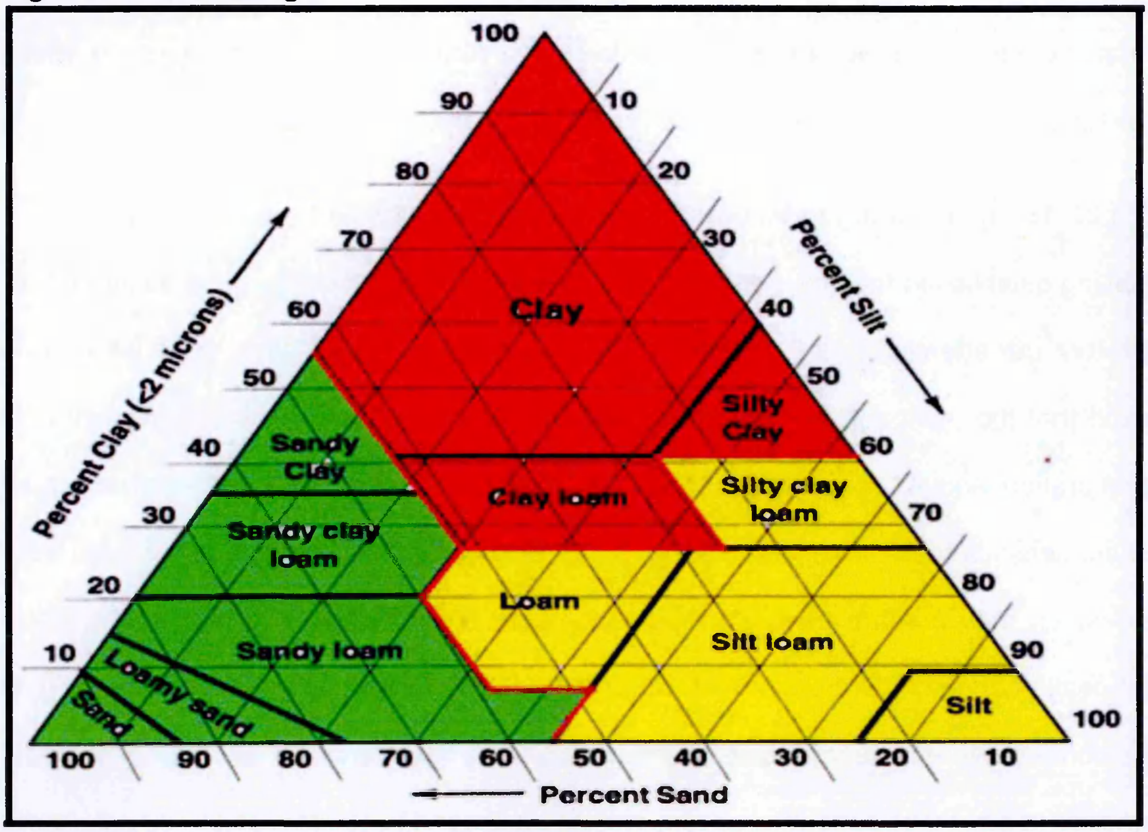
A power tiller or a tractor which is fit for purpose should complete farm work on time, adequately prepare the soil to suit the crops and also be easily operated and repaired by the users. A power tiller or tractor may possess all the characteristics that makes it fit for the operation and technical conditions of the farmer in question, but if the farmer's/farm's financial circumstances (availability of savings or opportunity to borrow investment capital) is inadequate, then access may be impossible through personal or communal ownership. Availability of savings usually depends on farm income which is influenced by crop type, farm size, soil fertility and the markets for inputs and products. Investment capital availability also depends on the presence and willingness of financial institutions and intermediaries to lend to farmers. Under circumstances of capital constraint, farmers resort to hiring from neighbouring farmers or rural entrepreneurs who own power tillers and tractors for contract work. Such a strategy is not always reliable, since owners will normally finish their own farm work before considering hiring their machine out to other farmers. Whether the farmer decides to buy or hire tillage equipment for land preparation, a good choice can be made if the texture and structure of the soil is considered.

5.3.1 Soils

Soil classifications are important for choice of power tiller and tractor discussions. This is because, different soil textures have telling implications on soil resistance faced by power tillers and tractors during traction. This consequently tests the quality of the machine, all things being equal. Soil texture, based on broad particle classes can be sandy, loamy or clayey; and on this gradation of sand, silt and clay combinations, energy requirements for tillage generated by power tillers and tractors will also vary. Texture refers to the size of the particles that make up the soil.

The terms sand, silt, and clay refer to relative sizes of the soil particles. Sand, being the larger size of particles, feels gritty (coarse). Silt, being moderate in size, has a smooth or floury texture (medium). Clay, being the smaller size of particles, feels sticky (fine). Soil particles whose diameter is below 0.002mm are considered to be clay; 0.002 to 0.05mm, being silt; and 0.05 to 2mm is sand. Particles above 2mm are considered to be gravels. Soils in general do not however occur as independent sand, silt and clay. They occur in a combination of these particles, and depending on the type of particles which dominate we can have general classifications as sandy (usually constituted by 50% or more sand), clayey (constituted by more than 50% clay) and loamy (in which the proportions of the three particles are approximately equal). Figure 5.1 is a soil triangle showing the various combinations of sand silt and clay possible, with the area coloured red being clayey, yellow being loamy and green being sandy. (Whiting et al., 2011).

Figure 5.1: Soil triangle



Source: Adapted from Whiting et al., 2011

On average soil resistance to traction machines (in the case of farmers under study, ploughs) for sandy (coarse and soft soils), loam (medium textured or tilled soils), and clayey (fine textured and firm soils) are 600 pounds per foot, 920 pounds per foot and 1200 pounds per feet respectively. This is approximately in the ratio of 1:1.5:2 (Siemens & Bowers, 1999). Thus for the same kind of land preparation operation on the farm, more energy is required to accomplish it on firm and fine textured clay soils than medium textured loam soils, and lose sandy soils in that order. The nature of the soil surface (concrete, firm, tilled or soft) also defines to some extent the friction generated between the soil and the tyres of tractors. This friction effectively affects the draft force for pulling farm implements. Thus whether the soil is clayey, loamy or sandy will inform the choice of power tillers and tractors in terms of quality and power. Because action and reaction are opposite and equal, the soil exerts a force proportionate to that exerted by tractors or power tillers. Thus for heavy textured soils, power tillers made of hardened metals are needed to forestall frequent damage. Below in Sub-section 5.3.2 we discuss some characteristics of power tillers and tractors, and further delineate the soils on which particular machines are fit for purpose (Walters, 2013).

5.3.2 Tillage capital goods: engineering characteristics and quality

Having established the types of soils and the relative resistance they pose during tillage, we turn our attention to the capital goods available for mechanisation. Here we bear in mind that the main use to which farmers in the study area put their machines are land preparation and to some extent, transportation. Discussing the design and technical characteristics that differentiate various types of power tillers and tractors and the soils on which they perform best, we must not ignore the differences in materials used in fabrication and standardizations adopted by producers. Thus, though two machines may be comparable engineering wise, if the metals used for fabrication are not of the same quality, then their performance on similar soil conditions will differ. As a result, differences in breakdown frequency and machine lifespan will also be observed.

Based on the engineering design, power tillers can be classified into two types; those whose rotary implements are propelled by power from the engine through a drawbar and those which are propelled by the force created by the moving power tiller: engine propelled (EP) and motion propelled (MP), respectively (Field survey, 2012). Generally power tillers are supposed to be walk-behind, but in some cases it is provided with a rear wheel to support a seat for the operator. Large tractors on the other hand can be categorized into three types, based on the wheel systems: two-wheel drive (2WD), front-wheel assist/unequal four-wheel drive (FWA) and four-wheel drive (FWD). Another way of categorizing power tillers and tractors is based on their horsepower. The horsepower of power tillers and tractors is a measure of the rate with which work or farm operations are carried out. In sum, one horsepower is the amount of energy required to move 33,000 pounds of soil a distance of one foot in a time span of one second. It is a measure of a machine's ability to move a load. By horsepower classifications we have small (5 to 24Hp), medium (25 to 49Hp) and large (50Hp and above). The maximum power developed by the engine of the tractor is known as the brake horsepower. The power-take-off (PTO) horsepower which is about 85% of the brake horsepower is the stationary power generated at the end of the shaft of the tractor connected to the engine. (Sumner & Williams, 2007).

A third classification of the horsepower is the drawbar horsepower which measures the pulling power of the engine in relation to the wheels. It is also a percentage of the PTO power and varies depending on whether the soil surface is compact or soft and the type of tractor (Walters, 2013). Thus, as the strength of the contact surface decreases, the drawbar horsepower also decreases because the grip and friction between the soil and the capital good declines. This means that on more compact soils, tractors are likely to develop higher drawbar horsepower. Generally, as horsepower increases, the weight of the capital goods which influences its stability during operation also increases by engineering design.

These different horsepower ranges of tractors also come with differing weights, number of engine cylinders and fuel tank volumes. A typical small power tiller of less than 25Hp has one or two cylinders. Medium sized tractors of less than 50Hp will have 2 to 3 cylinders while large ones have between 3 and 6 cylinders. Generally the higher the horsepower the more cylinders the machine possess, the heavier it is and the bigger the volume of the fuel tank. See Table 5.1 showing these broad categories and basic characteristics.

Table 5.1: Classification of capital goods features, scale and technology

	Scale			
Features	Power tiller	Tractor		
Size	*Small*	*Medium*	*Large (tier 1)*	*Large (tier 2)*
Number of engine cylinders	1 to 2	2 to 3	3 to 5	4 to 6
Brake horsepower	<25	25-49	50-84	85-450
Wheel system	EP/MP	2WD	FWA/4WD	4WD
Weight of machine (kg)	225-599	600-999	1000-1399	1400-2500
Volume of fuel tank (litres)	2 to 3	6 to 8	20 to 30	up to 300

Source: Field Work, 2012

In discussing optimal equipment under various farming systems, the study assumes that soil conditions are well drained, undulating and without heavy gravels and stones. In this light, machines with higher horsepower will be required to produce higher draft for heavy soils and vice versa. On very muddy soils FWA and FWD tractors are recommended for high quality traction. In addition, the strength of the machinery must also match the soil terrain. Tougher machines are recommended on fields which are rough, with high presence of rubbles and stones. At the same time not so tough machines would survive on relatively smoother and softer soils without difficulty.

The size of the farm in acres, which is sometimes related to the type of crop, also matters. For many crops[13], larger farms will require larger and faster machines that can complete operations on time. On smaller farms, small machines are sometimes ideal for easy negotiation of curves at the corners of the field and general manoeuvrability. However, no matter how small the field is, if the soils are very heavy, then small machines selected should be very tough. In the case of very wet grounds, the machine should not be too heavy so as not to sink and get stuck. It should also not be too light to prevent slipping. If they are heavy, then the wheels must be specifically designed to handle wet terrains. As small machines would take longer time to complete a unit area of work, labour availability is also important.

Whilst the question of quality of machine can be a subjective matter, and any assessment of quality by a user can be biased by personal views, its measurement or implied measurement is crucial to the analyses in this study. This is because, for most of the characteristics described above, emerging economy manufacturers tend to produce an array of products that mimic the advanced country products. However, their quality, durability and robustness in the view of importers, distributors and users are not always the same. To measure power tiller and tractor quality, average economic life of groups of

[13] In the case of a crop like tea, high quality objectives may require that cultivation by hand is maintained

machines is used as a proxy[14]. User experiences suggest that the durability of different brands of power tillers and tractors vary. Agents in the various links of the value chain put different brands of power tillers and tractors under a lifespan related quality class (Field interviews, 2012).

In reference to this assessment by users in particular, the study classifies machines which operate for up to 3 years from the time of purchase and then require major engine repairs as lower quality (Q1) and those which do so after 10 years are classified as higher quality (Q5). In between these two extremes of quality, we have 3 to 4 years (low – Q2); 4 to 6 years (medium – Q3); and finally 6 to 10 years (High – Q4). A breakdown of these quality classes is presented in Table 5.2. Despite the fact that these classifications may raise questions about justification of groupings, we argue here that more durable machines are likely to be made of high quality materials and hence likely to be tougher and more resilient to soil resistance.

Table 5.2: Durability and quality ratings of capital goods

Economic life (years)	0 to 3	3 to 4	4 to 6	6 to 10	10 and above
Quality ratings	Lower	Low	Medium	High	Higher
Codes	Q1	Q2	Q3	Q4	Q5

Source: Key informant interviews, 2012/2013

5.3.3 Farming systems, common crops and appropriate capital goods

There are two broad groupings of agricultural systems in Tanzania reflecting the main source of water supply: rain-fed and irrigated (See Dixon *et al,* 2001 for categorization of farming systems in sub-Saharan Africa). *Rain-fed* systems are mainly reliant on rainfall. Land preparation is done just before the onset of rains, or in some instances the early days of the rainfall. Ploughing and harrowing are timed to occur before the rains. However activities like mounding and ridging are left until the rains come since those operations are better done with some amount of moisture in the soil. *Irrigated* systems are fed with water directed from a river through canals or artificially pumping water from

[14] Repair and maintenance costs and frequency of breakdown are also considered

a dam or an intake point on a river. Underground water sources may also be used. Under this system, plots can either be totally flooded as in the case of paddy cultivation or just sprinkled in the case vegetables. These irrigated fields in Tanzania are usually found around river basins. A case in point is the paddy farms in the Mbeya region which derive water from the River Ruaha (Field interviews, 2012).

Common crops grown by Tanzanian farmers in our sample include maize, paddy (rice), pulses and legumes, sunflower, tobacco and sugarcane and some vegetables (onion, tomato - on very small number of seed beds generally not requiring mechanisation). Pulses and legumes (groundnuts and pigeon peas) and sunflower are grown as intercrops with maize. Pure stands of sunflower or pulses are usually uncommon. Maize farms are on average larger than paddy farms and paddy farms are also on average larger than sugar cane fields. Tobacco fields are generally commercial. The value of crop harvested per acre from these different crops in different parts of the country is not the same. Availability of suitable lands, ability to irrigate, intensity of cultivation, and general crop husbandry practices accounts for these differences. Below we consider each of the crops, their soil requirements and the associated capital good required to match them. Maize and rice are mainly produced by small and medium scale farmers for food with the intention of selling the surplus, whilst large scale farms mainly cultivate them for commercial purposes. Tobacco and sugarcane farmers have commercial orientation and produce for cash (See Sarris *et al,* 2006).

a. Typical food crops

i. Maize

Maize can be grown on a wide variety of soils, but performs best on well-drained, well-aerated, deep loams and silt-loams containing adequate organic matter and well supplied with available nutrients. Although it grows on a wide range of soils, it does not yield well on poor sandy soils, except with heavy application of fertilizers. On heavy clay soils, deep cultivation and ridging is necessary to improve drainage. It does not tolerate water logging; it can be killed if it stands in water for as long as two days and thus is rarely cultivated on deep clays where water logging is common. Therefore maize and millet farms intercropped with pulses are rarely irrigated; they are mostly rain-fed on relatively light to medium sols.

Most often small and medium scale maize farmers rarely have tractors. They usually prepare their land with hand hoe, oxen plough or hire the services of a tractor from other owners. Some medium sized farms and most large scale ones have tractors. Because of the relatively larger farm sizes, power tillers are rarely an option for farmers considering buying machines for their maize fields. However, because the soils on which maize is cultivated are lighter in texture, medium-sized tractors (25 to 49Hp) are very convenient. Under the rare occasion of medium textured soils, large tractors (tier 1) with FWA are preferred. Depending on how large the farm is and the time available to the farm operator for land preparation, some farms require more than one unit of the tractors described above; or simply work the single tractor for longer hours. The predominantly lighter nature of soils on which maize grows means that tractors with the two-wheeled drive technology are convenient, and it is not always necessary to have a four cylinder-engine; the three-cylinder versions can perform equally well.

With soil fertility declining in many regions of Tanzania, one way to compensate for decline in output is to increase area under cultivation, especially in the absence of fertilizers. To mitigate the negative effects of unexpected shocks like drought, households are cultivating larger area in places where the land is available at low cost. Consequently maize farms are growing in size in the sampled districts. Thus, larger machines (horsepower wise) are needed for timely completion of field operations. The sandy nature of the soils also means that not so much stress is put on the tractors- thus tractors made with low to medium carbon steel can withstand the soil resistance without breaking down.

ii. Rice

Wetland rice is grown on practically all types of soils, from sandy loam to heavy clay. It is however well established that the heavy soil characteristic of river valleys and deltas are better suited for wetland rice production than lighter soils. An ideal rice soil should contain up to 50-60% of finer fractions of silt and clay. Many wetland rice farmers practice paddling on demarcated plots. During land preparation paddling is done to level rice fields to evenly distribute irrigation water and to prevent pockets of stagnant water. Upland rice refers to rice grown on both flat and sloping fields, prepared and seeded under dry conditions, and depends on rainfall for moisture. Here, the soil is mostly clay and silt-loams reflecting the capability of the soil to absorb and hold enough water after the rains to support plant growth. Thus for rice, there are both rain-fed and irrigated systems, with the irrigated system having much heavier clays (Ceesay, 2004).

Rice farms can be small, medium or large scale. The intensity of farming operations on rice farms is high. Thus no matter the farm size, mechanisation is recommended to make farm work easier for the farmer and also help overcome challenges associated with labour supply. For both upland and irrigated fields, the soils are heavy and require power tillers and tractors made of high quality material and high horse power for medium to large scale fields. For the ploughing process on small fields, high quality and robust power tillers (small technologies) are recommended. Any attempt to use fragile and less robust machines on such farms will destroy the power tillers after a few days of usage. Depending on the nature of the soil, one can use one of three technologies. On relatively smooth soils without debris, power tillers with the rake technology[15] can be used for paddling. However if the soil particles are rough with a lot of debris, then a relatively low quality power tiller with high horse power (16-20), or a high quality power tiller with lower

[15] The rake technology does not draw energy direct from the engine; it works using energy from the motion of the power tiller

horse power (12-14) which comes with the rotor[16] technology can be used to break soil clods and agglomerations of soil under water (Field interviews, 2012).

On large upland farms, bigger and stronger machines are required (Tier 1 large tractors with FWA). Low quality machines can barely get any work done without breaking down. Tractors with 2WD complete work much slower; making it a risky choice under rain-fed conditions where timeliness is key. Here again, though 4WD drive technology is not a necessary engine technology requirement, it is an added advantage.

Large irrigated rice fields on the other hand, have much heavier soils. Thus soil resistance to tractors working on them is very high; the window for completion of the farming operation can also be limited. Thus tougher and more rugged machines are fit for purpose. The tyres must be well designed to create enough friction on wet soils to prevent slipping. The engine capacity must be high (Tier 1 large tractors with 4WD or Tier 2 large tractors) to create the desired furrow depth in the soil. Here 4WD is desired. However, high-end high-quality medium-sized tractors between 50 and 60Hp may also work; but not at a very fast pace. Low quality tractors usually lose some parts through breakages each time it is subjected to such conditions.

b. Typical cash crops

i. Tobacco

Grown in well-drained, sandy to loam soils tobacco is mainly cultivated for export markets from Tanzania. The soils are light and usually slightly sloping to prevent water stagnation. They are rarely planted on clay soils and mostly rain-fed. Because the soil is light, organic matter content is also low and most farmers fertilize their farms. Some farms inter-crop tobacco with onion and tomato, also under rain-fed conditions. Much like maize, soils on tobacco farms are usually sandy to sandy loams, very light in texture, and this poses lower resistance to tractors and their implements during land preparation.

[16] The rotor technology draws power from the engine during usage

Most tobacco farms are very large, and in cases where they are small the cultivation is by a collection of farmers under an out-grower scheme and sharing machinery resources. To cater for the larger farm sizes, machines with higher horse power (Medium sized and Tier 1 large tractors) are preferred by users to get farm operations completed on time. However, the material quality for fabrication of the machine need not be very high, though this can be an advantage in terms of lifespan of the machine. The activities carried out on tobacco fields are not so demanding when considering the soil resistance, but in terms of land area and the number of operations per acre, it is. To get the seed bed ready, the farmer ploughs, harrow and make ridges. This requires higher machine capacity to complete the work on time. Thus even if the farmer cannot buy machines of high quality and horse power, he/she could buy a number of medium-sized machines of relatively lower quality (in terms of strength of material used). Because of the large scale of nature of tobacco fields, 4WD engine technology is desirable.

ii. Sugarcane

A well-drained loamy soil is considered ideal for sugarcane production. The soil should be loose and friable with a minimum depth of 45 cm. However, deep and friable soils are not very common in loams. Clay soils offer the opportunity for deep top soils, thus most sugarcane farms in our study are found on heavy clay fields where water supply is adequate. Where the soils are hard due to clayey structure, more elaborate preparatory cultivation practices like deep-ploughing or chiselling are necessary before formation of furrows. Sugarcane has the potential for deep rooting and the crop growing in deep soils have appreciable drought tolerance. However the need to stimulate sugar contents at particular times of the year requires that irrigation water be pumped on the crop especially on large scale farms. Thus sugarcane falls under the irrigable lands, and particularly so under heavy clayey conditions.

Depending on the size of the farm, tractors of 60Hp and above can be used to prepare sugar cane fields. However for the purpose of sub-soiling or chisel ploughing, if a tractor is used it should have a horse power of about 80, otherwise chisel depth will not be good enough to prepare the whole topsoil for holding adequate water for the entire cane sugar plant life. Low quality and low horse power tractors will not survive a season on sugar cane fields especially in alluvial river basins. For best performance, materials used for such tractors must be hardened carbon steel. Power tillers are rarely used on sugar cane fields. But if the plot is very small, about an acre or two, high quality power tillers can perform the required task. Four-wheel drive tractors are usually of more value on such fields than tractors which have only the rear tyres being driven by the engine.

5.3.4 Summary

Table 5.3 presents a summary of the farming systems, the textural combinations (sand, silt and clay) of predominant soils and their associated common farm sizes. Maize and tobacco farms cluster around rain-fed systems on light to medium textured soils (Cell 1 and Cell 4 in Table 5.3). Upland rice and semi-irrigated sugarcane are rain-fed but usually found on medium to heavy textured classes of soils (Cell 2 and Cell 5 in Table 5.3). Finally we have irrigated rice and sugarcane occupying Cells 3 and Cell 6 in Table 5.3, where the soils are medium to heavy textured under the irrigated systems. Vegetables, legumes, sunflower and pulses are mostly intercropped with maize and tobacco in Cell 1 and Cell 4.

Table 5.3: Farming systems, crops and soils

Farming System	Soil texture	Food Crops		Cash Crops	
		Maize	Rice	Tobacco	Sugarcane
Rain-fed	Sandy (coarse and loose)				
	Loamy (medium and light)	Cell 1		Cell 4	
	Clayey (fine, firm and heavy)		Cell 2		Cell 5
Irrigated	Sandy (coarse and loose)				
	Loamy (medium and light)				
	Clayey (fine, firm and heavy)		Cell 3		Cell 6

Area Red- Maize
Area Blue- Rice
Area Yellow- Tobacco
Area Green- Sugarcane

Cell 1- Rain-fed maize sandy-loam
Cell 2- Rain-fed rice clayey-loam
Cell 3- Irrigated rice clayey-loam
Cell 4- Rain-fed tobacco sandy-loam
Cell5-Rain-fed sugarcane clayey-loam
Cell6-Ireigated sugarcane clayey-loam

Source: Field work, 2012/2013

These sets of farms (characterized by crops, soils and water source) on average have minimum technology requirements for best performance defined by the horsepower, the wheel-system and the quality of the tractors or power tillers (See Table 5.4). Based on key informant interviews in 2012, the study found that small scale maize farms under rain-fed conditions would require a tractor with a minimum of 25Hp to 49Hp, 2WD and at least a quality grade of Q2. In the case of medium scale maize farms, the specifications required are at least 25Hp to 65Hp, 2WD and Q1 to Q2 quality rating. A 35Hp to 65Hp, FWA, and Q2 are best suited for large scale maize farms. Tobacco fields are similar to rain-fed maize, apart from the fact that they are usually medium to large scale and so the machines specified for maize are equally fit for purpose.

Table 5.4: Optimal technologies (engineering and quality)[17]

Farming System	Soil texture	Food Crops						Cash crops			
		Maize			Rice			Tobacco		Sugarcane	
Rain-fed	Sandy	25Hp-49Hp; 2WD; Q1	25Hp-65Hp; 2WD; Q1 to Q2	35Hp-65Hp, FWA, Q2				25Hp-65Hp, 2WD and Q1 to Q2	35Hp-65Hp, FWA, Q2		
	Loamy					35Hp-65Hp; FWA;Q2 and Q3	50 to 80Hp FWA/4WD; Q2 and Q3			35Hp-65Hp; FWA; Q2 and Q3	50Hp-80Hp FWA/4WD; Q2 and Q3
	Clayey										
Irrigated	Sandy										
	Loamy				12Hp to 24Hp; EP; Q4 to Q5	50Hp to 80Hp; FWA/4WD ; Q4	65Hp or more; 4WD; Q4 to Q5			50Hp-80Hp; FWA/4WD; Q4	65Hp or more; 4WD; Q4 to Q5
	Clayey										
Farm size		Small	Medium	Large	Small	Medium	Large	Medium	Large	Medium	Large

Area Red- Maize Area Blue- Rice Area Yellow- Tobacco Area Green- Sugarcane

Source: Field work, 2012/2013

[17] **Quality classes of capital goods based on lifespan/durability as a proxy**

Economic life (years)	0 to 3	3 to 4	4 to 6	6 to 10	10 and above
Quality classes	Lower	Low	Medium	High	Higher
Codes	Q1	Q2	Q3	Q4	Q5

Source: Key informant interviews, 2012/2013

Similarly, rain-fed rice and sugarcane are grown on loamy to clayey soils under medium to large scale holdings and so machine specifications appropriate for one are good for the other. On the medium scale, a 35Hp to 65Hp, FWA and Q2 or Q3 quality is the best bet; whilst on the large scale farms, 50 to 80Hp, FWA/4WD and Q2 or Q3 is the minimum required. Finally on the irrigated systems where we have rice being cultivated on all three farm sizes and sugarcane on medium to large scale, higher technology specifications of technologies are required. However, for the small scale rice fields, power tillers of 12Hp to 24Hp, engine-propelled and of Q4 to Q5 quality rating, are optimal. For both rice and sugar on medium and large scale, a 50Hp to 80Hp, FWA/4WD, Q4 tractor and a 65Hp or more, 4WD, and Q4/Q5 tractor respectively are adequate.

5.4 Study sites and farming systems

On average, the distance between the communities under consideration and their regional capitals is about 80km. The distance to the commercial capital Dar es Salaam where quite a number of farmers buy machines and spares, on the eastern coast, varies between sites. Dakawa is the closest to Dar es Salaam, 244km; and Mbuyuni is the most distant (746km). The closest community to a regional capital is Gallapo (17km) and the furthest is Ubaruku (130km). (Table 5.5) In the following subsections, we describe the study sites and identify the common soils and farming systems and then finally match these communities with common agro-economic blocks identified in Table 5.3 and 5.4. The discussions here are based on interviews conducted with users, community leaders and other key informants in 2012.

Table 5.5: Regions, communities and samples drawn

Region	Community	Distance to regional capital (km)	Distance to Dar es Salaam (km)
Dodoma	Hembahemba	111	354
	Ngomai	112	356
Iringa	Ilula	47	454
	Nzihi	40	541
	Pawaga	72	573
Manyera	Gallapo	17	653
	Magugu	58	715
Mbeya	Mabadaga	106	738
	Mbuyuni	98	746
	Ubaruku	132	719
Morogoro	Dakawa	50	244
	Turiani	95	289

Source: Field Work, 2012/2013

5.4.1 Morogoro (Mvomero District- Dakawa and Turiani)

Dakawa hosts the Dakawa Irrigation Scheme, formerly government controlled and over time transferred to individual farmers. Farming activities here are mainly organized around paddy cultivation; however other crops like maize are cultivated on a relatively smaller scale. The soils are thick black clays that experiences cracks during the dry season. The soils are very heavy and many farmers dread its impact on farm machinery. Even in the wet season, there is evidence to suggest that it takes quite a long time before water is able to percolate and rebind the soil particles. The heaviness and stickiness of soils in this area is also demonstrated through the existence of many small scale brick factories which depend on the abundance of this natural raw material, clay. The soils are also characteristically black because of the presence of a lot of organic matter mainly from fibrous rooted grasses and sometimes some stumps of shrubs or broad-leaved weeds. There is a lot of sunshine in this area and the soil fertility, is very high and good for the cultivation of rice. However continuous usage of the parcels of land in the area without inorganic fertilizer application, especially in the early days, has resulted in declining fertility. Dakawa's agriculture generally involves either rain-fed or irrigated rice fields, dominated by heavy clay soils (See Cell 2 and Cell 3 on Table 5.3).

Dakawa is on the main road between Morogoro town and Dodoma town. Thus access to regular commuter transport, reliable pipe borne water and electricity exists. The town is dotted with small corner shops which sell spare parts for motor bikes and also repairs them. Some of these shops have stocks of tractor spare parts. During the land preparation season- around October, November and December, shop keepers increase the stocks of such spare parts. During these months, tractors from other regions like Dodoma and Manyera, where land preparation begin in January come around to participate in contract hiring. This increases the tractor stock and causes a surge in demand for spare parts. There is also a common rice storage facility in the town centre, which doubles as a marketing point for paddy or milled rice where people from Dar es Salam and Morogoro come to buy in bulk.

Turiani area (which means settlement), is about 60km from Dakawa. This settlement has evolved with the establishment and development of the Mtibwa Sugar Estates one of four cane production and processing sites in the country. The estate farms as well as out-growers and its accompanying processing plant currently produces and distributes about a sixth of all table sugar consumed in Tanzania (Key informant interview, 2012). Economic activities around the estate, in terms of trade, commerce and artisanal services are intense. Though more than 50km off the Morogoro-Dodoma main road, it is more urbanized and active than Dakawa. The soils are even heavier and deeper. Farmers around the estate, cultivating sugarcane and paddy, usually use tine cultivators as a pre-primary tillage technique before setting out to do an ordinary ploughing (either dry or wet). The soils here are much heavier than those in Dakawa and it is evident in the fact that many of the tractors are large and with higher horse power. As one businessman who sells spare parts and also doubles as a trained mechanic puts it:

> *...'in Turiani a farmer cannot be in business without a Ford or New Holland; they have been tried and tested here, but even so anything below 70Hp is a non-starter".*

Muddy areas are also common and the area looks much greener than the Dakawa area. The sugar fields, especially those operated by the estates are irrigated with river water available during most of the year. The fertility of the soils is also higher and the farmers here grow a variety of other food crops. Aside from the usual sugar cane, rice and maize are also cultivated. The rice and sugarcane fields which dominate in this area are mostly irrigated on clay soils, but a few are rain-fed. Thus typical farms here fit Cell 3, Cell 5 and 6 in Table 5.3.

With unreliable sugar content in cane, and low prices of sugar which are generally not paid on time by the estates, an extension officer made me aware that most of the out growers are now allocating more farm lands to the cultivation of rice instead of the traditional cane sugar. The town is also dotted with a lot of repair shops for maintaining tractors. There are however three large repair shops which most owners use. Expertise in the maintenance of Ford, Fiat and New Holland tractors is widespread. Most of the mechanics operating these garages were formally employees of the sugar estates and upon retrenchment, opened their own garages. Activities in terms of service provision are swift and the connection between owners of tractors and particular garages is also very relational.

5.4.2 Mbeya (Mbarali District- Ubaruku and Mbuyuni)

Mbeya is characterized by dry spells, dusty and windy conditions. There are two separate irrigation schemes, Mbuyuni and Ubaruku. The Mbuyuni scheme is manned and managed by farmers on the scheme and supervised by extension officers from the Ministry of Agriculture, while the Ubaruku scheme, a formally government controlled estate known as Mbarali Estate has now been diversified and it is operated with private equity. Central government have very little oversight of the estate now. Covering an area of about 3,100 acres and with about 150 members, the Mbuyuni scheme which is on the Iringa-Mbeya main road, was renovated with the support of the Japan International Cooperation Agency (JICA) in the late 1990s with redevelopment of canals and preparation of the sub and top soils and then levelling. Water intake points were also improved. In addition to the improvement of physical infrastructure, soft technologies were also transferred to members of the scheme by the Japanese to improve their production strategies and consequently improve output and ultimately income. Prior to the 2000s, the scheme was mainly tilled with animal power. However, the extension officer reports that the animal power stock on the field has declined greatly and scheme members have agreed that by end of 2013 season, the use of animal power should be eliminated altogether (Key interview with extension officer at Mabadaga, September, 2012).

There are thus currently 120 power tillers and about 5 tractors on the scheme mainly for primary tillage operations and gradually phasing out the use of animal power. One fifth of all power tillers on this scheme are owned by women and of the three spare parts shops in the community, one is owned by a woman. The rural market and entrepreneurship in terms of sale of farm machinery, spare parts and expertise in repairing power tillers and tractors is at an infant stage. This is because Mbuyuni is surrounded by relatively bigger and more active communities including the district capital Rujewa, about 32km away and Chimalla, another big town in an adjacent district. Thus with reliable transport, farmers are not worried about commuting for purposes of purchasing whatever spare parts they may need.

The Ubaruku scheme is privately owned by an Indian investor. There are two plots which altogether comprise 3,200 hectares. While the managers of this estate reserve a substantial part of the land for their own cultivation, there is also a portion given to interested community members to use for their household production. In such an arrangement between households and estate owners, usually with a three year renewable contract, the company ploughs the land and supplies water to the users at an annual fee of TZS100,000 (£42.00). What the households do on these fields is usually secondary, tillage mainly paddling, planting and weeding. However in cases when the ploughing done by the company is not to the users' satisfaction, then they will plough again before paddling. There is another open source scheme, managed by the community to supply water to farms which are outside the Mbarali Estate Scheme. Here, farmers only pay an annual fee to use the water, but carry out all other activities by themselves. Present in Ubaruku are other large farms managed by private individuals which are rain fed.

The local Roman Catholic Church also has a fleet of tractors, which they use to till their irrigated fields. With a population of about 35,000 people, the streets of Ubaruku are lined with power tillers either being displayed for hiring, waiting to be repaired or just an operator who has pulled off to get a drink. Once in a while, the ear-shattering noise of a power tiller carrying bricks or bags of paddy rice from one point to another is heard. In total, there are over 300 power tillers owned and used by farmers in this area. Large scale farmers also have between 30 and 35 tractors working on their fields. This excludes about 50 tractors owned and used by the Catholic Church and Mbarali Estate. This is based on estimates made by extension officers and other farmers who have been working in the area for years.

In the industrial area of Ubaruku warehouses built specifically to store paddy rice and serves as a trading point for people who have come from other regions and neighbouring countries to buy rice. There are four large scale rice milling plants owned by local entrepreneurs who are themselves farmers. They provide storage facilities for farmers and also mill and grade their produce for them at a fee. The predominant crop grown here is paddy, but some farms also grow maize, though not irrigated and mainly produced for household consumption. Both Mbuyuni and Ubaruku schemes clearly fit on Cell 3 whilst the upland farms in Ubaruku fits in Cell 2 in Table 5.3.

5.4.3 Iringa (Iringa District - Pawaga and Nzihi)

Iringa is a relatively cooler region with temperatures sometimes falling to 7^0C in mountainous areas. The standard of living is also quite high in terms of average household incomes compared with other regions considered in this study and the rest of the country as a whole. Soils here are not very heavy but not too light also, especially for areas in the district under consideration where tobacco, tomato and maize are grown. The soils can be described as sandy to light loams in the tobacco and tomato growing areas to medium clays on the paddy fields. The abundance of grasslands is also an attraction for a number of nomads rearing ruminants like cattle and donkeys. Supplied with a lot of water from the Ruaha River, some farmers along the basin cultivate paddy (especially in the Pawaga area) and others cultivate vegetables like tomato and onions around the Nzihi area. With large tracts of arable land in the low lying areas, the Iringa region and the district has been a source of attraction to many white settlers from Europe wanting to do business in the agricultural sector or just for tourism. To this end, there are several acres of land allocated to European investors who are mainly Greeks and a few of German origin.

The arrival of the Greek and German investors in the late 1950s and early 1960s in the Nzihi area (about 40km from Iringa town) served as a driver of mechanisation and the consequent introduction of tractors and other machinery mainly from Europe. In a small town around Iringa, legend has it that a particular Massey Ferguson tractor which I did not have the privilege to see during my study tour had been working since 1954. These Greek and German farms are usually large scale commercial farms mainly growing tobacco. Their estates are built in such a way that a village is artificially developed around it as home for migrants seeking jobs on the farms. The tradition has been that most Tanzanian farmers living around the estates usually buy second hand tractors from the large farms when they purchase new tractors. Thus until the early 2000s, not many locally owned farms in the towns in which this work was done, had bought their tractors as brand new.

In the Pawaga area, about 72km from the regional capital, Iringa, where there is very little participation of white settlers in the rural economy, farms were mainly operated with animal power until a few co-operative societies in the 2000s, started to buy tractors- for their members. Because the tractors were few, access was also limited, requiring the continual dependence on depleting animal power stocks and the hand hoe. However, with the advent of power tillers in the mid-2000s, the two main irrigation schemes around the Pawaga area cultivating rice, begun to purchase power tillers either on an individual farmer basis or through their co-operative societies. One of the two irrigation schemes have been well developed, with canals dredged and water supply maintained. The other scheme lacks structural and managerial excellence and so farmers on the latter scheme turn to rely more on hand hoes and animal power, compared with the former where there is evidence to suggest that they are mechanizing at a very fast rate. In addition farm animals, especially donkeys are also very prominent on the rice fields in this area. There is however anecdotal evidence to suggest that there is a latent demand for more power tillers, but the transportation cost associated with bringing the machines from Iringa or Morogoro is a disincentive to interested formers. It is likely that if road infrastructure improves, more power tillers will find their way into the area.

Road infrastructure between the regional capital and both study sites is not well developed. Frequent and reliable mini bus service between Nzihi and Iringa, the regional capital exists. On the other hand, there are only two big buses which make a daily round trip to Pawaga. On market days, which is once in a month there are more buses plying the route. The Pawaga area is also not connected with the national electricity grid and households power their homes with kerosene or power tillers connected to dynamos. The spare parts market, and repair shops especially for tractors are mainly found in the regional capital and so farmers usually travel to Iringa for service and spares. However on large (white) settler farms, they usually have their own mechanics and for people who have recently bought new tractors, they can call the dealer to come over for servicing if the warranty has not expired. Generally, the soils in Nzihi area are rain-fed loamy soils to light clays and those around Pawaga are irrigated fields of medium to light clay.

5.4.4 Manyara (Babati District- Gallapo and Magugu)

Babati is a newly formed region, but formerly part of the Manyara region (home to the highest number of tractors, as historical evidence suggests). Farmers in this area are mainly involved in the cultivation of maize, groundnuts and sunflower especially around Gallapo, about 17 km from Babati the regional capital. Magugu is also about 58km from the regional capital and cultivates mainly maize, paddy and sugar cane. Whilst maize is mainly cultivated by the locals, with a few on the irrigation scheme cultivating paddy, some Finish and Indian settler farmers cultivate sugar cane, rice as well as certified seeds for farmers. This region has two growing seasons per year; thus giving farming in the area better prospects than the other regions where the rains are usually once a year. Their location close to the Kenyan boarder and a traditionally prosperous region in terms of agriculture makes it integrated with other African countries in terms of input markets as well as an outlet for their produce.

This region has attracted a lot of investment in terms of coffee growers in the Arusha and Moshi areas as well as government support through the Lower Moshi Irrigation Scheme. They have also benefited immensely from an Agricultural Training Centre[18] in Moshi mainly concerned with paddy cultivation. In recent times, a research centre for the advancement of zero tillage technologies has also been sited at Babati and farmers in the area are receiving training in agro-forestry and conservation agriculture. Because of the high fertility of the existing loamy soils in the region, it has in the past and present attracted a lot of high quality mechanisation equipment.

[18]This is a training centre for equipping farmers with rice production technologies

In the Magugu area some small scale farmers have started taking delivery of power tillers, especially in the last two years through the assistance of the local government or their own personal savings. Their irrigation system is currently being improved through reconstruction, canal improvement and field levelling. Some farmers are of the view that when the scheme improvement is completed, coupled with the fact that there is a dealer of power tillers currently in Babati, demand for mechanisation equipment will surge. Soils in Gallapo are rain-fed sandy loam to loam (Cell 1 in Table 5.3) and those in Magugu are heavy loam to light clay (cell 3 in Table 5.3).

5.4.5 Dodoma (Kongua District- Hembahemba and Ngomai)

Soils in Dodoma are sandy to sandy loam. They are relatively lighter compared with all the other regions under consideration. Soil fertility is relatively lower, so are household incomes and levels of education. The rains are usually once per year, and very erratic. Deforestation has become a major problem as farmers clear large tracts of land to cultivate their crops as a risk coping mechanism. Thus in years when the weather is bad, because of the large area cultivated, the little they harvest per acre comes together to create enough output for household consumption and a little excess for sale. Most farmers in this area grow maize, sunflower and groundnut intercrops. Some of the farms are very close to the settlements; others are very far away from where they live. Some farmers in these two communities considered under our study actually go as far as the Manyera region (about 350km) to cultivate the maize crop, as land in their locality have degraded so fast, and further allocations made by central government as forest and game reserves has constrained supply.

The availability of fertile and unreserved lands in the area continue to diminish, in the midst of a surging demand for maize, after the opening of the maize market in Kibaigwa (a commercial centre in the district) a few years ago. Kibaigwa is about 15km from Hembahemba and 8km from Ngomai. Most of the villages that surround Kibaigwa are actively involved in the cultivation of maize and under very conducive environmental conditions they are able to produce as much as 10 bags per acre, while in bad years some farmers harvest as little as 2 bags per acre or nothing at all. Kibaigwa also serves as a market for spare parts and tractors. Mechanics specializing in the repair of mainly Indian Swaraj tractors are dotted around Kibaigwa and tractor owners from Hembahemba and Ngomai use them. Quite recently, the Swaraj Company also opened a distribution and service centre at Kibaigwa and they also serve farmers in the area. Though there are a lot of farm animals in the Ngomai area, animal power usage on farms has diminished greatly, and nowadays most of the primary tillage practices are conducted using tractors.

In the Hembahemba village where most of the surveys were done in this region, they trace their early experience with tractors as far back as the late 1970s when a rural entrepreneur had a milling machine which used a German made International tractor to operate. The same entrepreneur also used his tractor during the cultivation season to plough his land and those of other village members who were interested, and to the extent that time constraints allowed. Subsequently, the village took delivery of three International Harvester tractors under a government initiative to support agriculture in the rural areas. These machines were managed by the village committee and they served farmers under a hiring scheme.

During the Structural Adjustment Programmes, these machines were sold to some community members. This was probably the tipping point for private farmers to own tractors. At the onset, there were a few tractors which individual farmers bought either new or second hand, mainly from advanced countries. In the mid-1980s, some models of Swaraj were imported from India and over time they became popular. Between 1988 and 1994, there was another initiative by government to encourage farmers to own tractors. Under this programme Hembahemba imported Escort tractors also from India. The Swaraj groups continued actively marketing throughout the 1990s and towards the end of that decade, a few Powertrac tractors were also imported from India. Generally, soils in Dodoma fit Cell 1 in Table 5.5.

In Table 5.5, each of the study sites is placed in the Cell that matches its predominant farming system, soils, crops and farm size. Table 5.5 forms the basis for our comparison of technique choice.

Table 5.5: Study sites and agro-economic indicators

<table>
<tr><th rowspan="3">Farming System</th><th rowspan="3">Soil texture</th><th colspan="4">Crops</th></tr>
<tr><th colspan="2">Food</th><th colspan="2">Cash</th></tr>
<tr><th>Maize</th><th>Rice</th><th>Tobacco</th><th>Sugarcane</th></tr>
<tr><td rowspan="3">Rain-fed</td><td>Sandy (coarse and loose)</td><td rowspan="2"><u>Cell 1</u>
Ilula
Gallapo
Ngomai
Hembahemba</td><td></td><td rowspan="2"><u>Cell 4</u>
Nzihi</td><td></td></tr>
<tr><td>Loamy (medium and light)</td><td rowspan="2"><u>Cell 2</u>
Ubaruku
Pawaga
Dakawa</td><td rowspan="2"><u>Cell 5</u>
Turiani
Magugu</td></tr>
<tr><td>Clayey (fine, firm and heavy)</td><td></td><td></td></tr>
<tr><td rowspan="3">Irrigated</td><td>Sandy (coarse and loose)</td><td rowspan="3"></td><td></td><td rowspan="3"></td><td></td></tr>
<tr><td>Loamy (medium and light)</td><td rowspan="2"><u>Cell 3</u>
Dakawa
Ubaruku
Mbuyuni
Magugu
Mabadaga</td><td rowspan="2"><u>Cell 6</u>
Turiani
Magugu</td></tr>
<tr><td>Clayey (fine, firm and heavy)</td></tr>
<tr><td colspan="2">Average farm size</td><td colspan="2">Small/Medium/Large</td><td colspan="2">Medium/Large</td></tr>
</table>

Area Red- Maize Area Blue- Rice Area Yellow- Tobacco Area Green- Sugarcane

Source: Generated from Table 5.3 and Discussions in Section 5.5

In effect, these indices generate three distinctive situations under which a choice between advanced country and emerging economy tillage technologies can be made. First, Cell 1 and Cell 4 have similar agro-economic characteristics. Thus for Cell 1 (Ilula, Gallapo, Ngomai and Hembahemba) and Cell 4 (Nzihi) in Table 5.5 which have same farming systems and soils, tractors that are fit for purpose in the former case will also be fit in the case of the latter. Second, taking a similar approach, Cell 2 (Dakawa, Ubaruku, Mbuyuni, Magugu and Mabadaga) and Cell 5 (Turiani and Magugu) can be combined for the analyses of choice of technique as farmers under those two farming systems have similar soil characteristics. Third, Cell 3 (Dakawa, Ubaruku, Mbuyuni, Magugu and

Mabadaga) and Cell 6 (Turiani and Magugu) are also comparable and so can be combined when considering technologies which are fit for purpose.

It must be stated here that while tractors can be used under all the three scenarios categorized here, power tillers are mainly useful under small scale rice fields. Though manufacturers usually specify several conditions under which they can be used, field visits to most farms revealed that only a small proportion of farmers (6 out of the 95 power tiller owners interviewed) used their power tillers outside paddy fields. In Section 5.6, groupings of power tillers and tractors on the Tanzanian market based on the source of the soft and hard technologies are made. At the end of the Section 5.6, the five operating conditions discussed here are revisited and alternative brands from which the farmers within each scenario can choose from are presented referencing the farm level data. This will serve as the bases of our discussion on distinctive nature of capital goods in Chapter 8.

5.5 Mechanisation choice sets and alternatives

Beyond technical and engineering differences, there are global value chain structures and target markets which influence cost, quality and volumes produced of power tillers and tractors. As discussed in Chapter 2 of this thesis, there are four major centres for the production of tractors and three major centres for the production of power tillers in the world. These centres are dominated by fewer than fifteen large conglomerates. Aside from sourcing machines from these centres, attempts are also being made to produce power tillers and tractors locally in Tanzania. We shall discuss the options available to the farmer in Tanzania on the global market and the potential, in the future to buy from local manufacturers in the following sub-sections.

5.5.1 Brands from the international market

Power tillers are mainly produced in Japan (with subsidiaries in other Asian countries like Thailand), Korea, India and China. Historically, the original source of power tiller technology was Japan and production subsequently migrated to Thailand, Korea, India and China. The main centres of tractor production include USA (with plants in South America), Western Europe and India.

As was shown in Chapter 2, tractor manufacturing started in the UK and USA and gradually moved to other parts of the world (a case in point is India where in the 1960s joint ventures with American and European companies produced tractors locally). Global annual production of tractors stood at 1.8m in 2011. A third of this number was produced in India, making it the world's leading maker of tractors in volume terms (Rao, 2013) Of all the tractors produced in India, only 11% in terms of sales is exported (ICRA, 2012; Mandal & Maity, 2013). That is, in year 2012 when the volume of tractors produced in India were over 450,000 units, a little over 50,000 units were exported. This means that producers in India target mainly their home markets. European and American tractor makers target large scale farms in their own back yard and others across the world with better access to capital. India on the other hand produces for relatively smaller farms with capital constraints.

China is currently the largest producer of power tillers (both in value and volume terms) in the world. Chinese manufacturers of power tillers have their eyes set on local markets which are generally characterized by low income peasants who are gradually becoming mechanized. Japanese and Korean power tillers are produced in lower volumes and predominantly target relatively richer farmers in their own home and other well to do hobby farmers or companies maintaining housing facilities in advanced countries. Thus the old production centres are characterized by high cost high quality as opposed to the newer production centres which concentrate on cost innovations to meet budget constraints of users.

We therefore characterize the older centres of production associated with high quality and high cost (that is USA, Western Europe, Japan and Korea as) matured markets

(MM). Relatively newer centres of production like India, China and more recently Pakistan, are classified as emerging economies (EE) in this study. It must be emphasized here again that some MM companies have manufacturing sites located in EE either to take advantage of relatively cheaper factors of production or to produce for the local market (Stewart, 1977). Power tillers and tractors produced under such conditions rarely match the quality standards and cost of their original versions, though the deviations are not so high. As suggested by a farmer in the Dakawa area during an interview:

> ....I have two New Holland tractors, one from India and the other from Turkey...I have used the Indian machine for about 18 months and that from Turkey for nearly 24 months, as you can see, the one from India is already showing signs of old age...though I assign both of them practically equal amount of work per time. (Field work interview, 2012)

Furthermore, there are some MM machines which have been adapted to local conditions in the EE through licensing from original brand owners or joint ventures which are not as robust as those produced in the MM. As we shall see in later chapters of this thesis, the materials used in the fabrication of machines adapted to EE markets are not very strong and so there are frequent breakdowns associated during usage compared with the MM ones. As noted by a female power tiller owner in the Ubaruku area during a focus group discussion:

> "...my power tiller from China is relatively cheaper compared with those from Japan or Thailand. Sometimes I wonder if the machine is made of *clay*...because parts of it easily gets destroyed and in the past season I have had to make about 18 round trips to the district capital just to buy spare parts to replace broken down ones (Focus group discussions, 2012)

The main elements or features that constitute adaptation are cost reduction, and subsequently quality reduction. There are however instances in which electrical systems are simplified for easy operation and repair and in other instances air filters are doubled to prevent excessive gathering of dust in the engine. Finally, some technologies have also been developed in the EE and are produced locally. Thus the study classifies MM machines produced in advanced countries as MM_0; MM machines produced in developing countries as MM_1; MM technologies adapted to developing country conditions and produced in developing economies as EE_1; and EE technologies produced in developing countries and designed specifically for the EE, as EE_0. Table 5.6 presents these categories and their country of origin. There are some EE technologies which are also produced in and for advanced country users; these groups of machines are however not considered in this study.

Table 5.6 gives a list of the tractors and power tillers under the categories defined above. It must be emphasized here that the list in Table 5.6 is not exhaustive of all the brands in Tanzania.

The brands listed here represent all the machines in the data set from the field work. Typical MM_0 power tillers are Kubota, Kukje and Daedong. Siam Kubota made in Thailand, is an example of MM_1 power tiller on the Tanzanian Market. In the case of EE_1, VST Shakti and Greeves are examples, and they are produced based on engineering designs of Mitsubishi power tillers from Japan in India, Amec, Changfa, Dongfeng are typical examples of EE_0. Generally, spare parts of Amec, Changfa and Dongfeng can be interchanged for one another.

With reference to tractors, Ford, Fiat, Massey Ferguson, International Harvester, Valmet and Belarus are historical MM_0 brands that are still in use in Tanzania. It is possible to still purchase second-hand versions of Massey Ferguson and International Harvester in Tanzania. But second-hand Ford, Fiat, Valmet and Belarus are no longer available. Kubota tractor, SAME, John Deere, Case and New Holland are MM_0 tractor brands in Tanzania that can be purchased brand-new. Valtra (new trade name for Valmet from Finland and Brazil), Massey Ferguson (Brazil), New Holland (Brazil and Turkey) and John Deere (India) represent MM_1 tractors.

Table 5.6: Scale of technology, source and brand available in Tanzania

			Brand Name	Country of origin
Power tillers	MM	MM_0 (MM made in the North)	Kubota	Japan
			Kukje	S. Korea
			Daedong	S. Korea
		MM_1 (MM made in the South)	Siam Kubota	Thailand
	EE	EE_1 (MM adapted to EE, made in the South)	VST Shakti[19]	India
		EE_0 (EE made in the South)	Greaves	India
			Amec	China
			Changfa	China
			Dongfeng	China
Tractors	MM	MM_0 (MM made in the North)	Ford ^{h}	UK
			Massey Ferguson ^{h}	UK/USA
			Fiat ^{h}	Italy
			SAME ^{h}	
			International Harvester ^{h}	Germany
			Valmet ^{h}	Finland
			Belarus ^{h}	Russia
			Valtra	Finland
			Kubota tractor	Japan
			John Deere	USA
			New Holland	UK/US/Italy
			CASE	USA
		MM_1 (MM made in the South)	Valtra	Brazil
			Massey Ferguson	Brazil
			New Holland	Brazil/Turkey
			John Deere	India
	EE	EE_1 (MM adapted to EE, made in the South)	Massey Ferguson	Pakistan
			TAFE	India
			New Holland	India
			Powertrac/ Farmtrac	India
		EE_0 (EE made in the South)	Escort	India
			Mahindra	India
			Swaraj	India
			YTO	China
			KAMA	China

All machines labelled with superscript h are historical brands; new versions do not exist now so at best users can only procure second-hand versions

Source: Field Work Data, 2012

[19] VST Shakti has been adapted (cost innovation wise) using Mitsubishi power tiller technology from Japan.

Massey Ferguson (Pakistan), TAFE, Powertrac/Farmtrac and New Holland (all from India) are examples of EE_1 tractors. EE_0 tractors include Escorts, Mahindra, Swaraj, YTO and KAMA. Escort and Swaraj have been on the Tanzanian market for several decades; however Mahindra (the world's largest tractor producer in terms of volume) entered the market in 2010 and is yet to make significant inroads.

5.5.2 Local manufacturing of tractors and power tillers

Currently there is no full scale power tiller or tractor manufacturing in Tanzania. However, there is evidence of assembly of power tillers in Mwanza in the North Western part of the country by a private businessman. The company imports engines and gear boxes from Spain. Other parts of the power tiller are then fabricated in their own workshop and then manual assembly is done. This activity has been going on for well over 20 years. The quantities produced especially in the 2000s declined significantly as the business owner experienced a number of financial challenges. The engine manufacturer in Spain is also believed to have folded after the 2008 financial crises and this has created a further input supply gap. The machines they produce are robust, but come with advanced country cost, which are prohibitive to low income households. The plant manager and technicians were of the view that as the name suggests, capital goods must be durable and robust. To get these qualities of robustness and durability, prices cannot be reduced further. The company however plans to now import Indian engines and gear boxes in the future when the business rebounds (Key informant interviews with power tiller Plant Manager in Mwanza, 2013).

In the tractor market, government research institute (CAMARTEC) is leading the way for domestic manufacture. The institute imports engines from the UK and fabricates the other components locally. Though yet to go commercial, field trials with prototypes across the various regions of the country is currently underway. In its current form, the Director of Research believes it will be affordable to users and also meet the needs of the Tanzanian terrains. They are however concerned that raising local capital to commence production has been extremely difficult, and they do not think that government in its present form will participate to an appreciable extent (Key informant interview with Testing Officers and Mechanical Engineers in Arusha, 2013).

On the FDI front, there are negotiations by some international manufacturers such as Iran Tractors and M&M of India to begin feasibility studies for producing tractors in Tanzania. Several industry players are explicit about the fact that with the current demand structure, anyone who wants to manufacture tractors in Tanzania must consider pricing as very important. Household incomes are low, there is low country-wide capital base and banks lend more to non-agricultural businesses. These capital constraints requires extensive planning for local manufacturing to thrive and it should be pursued in the context of the East African market, rather than concentrating solely on Tanzania (Key informant Interview with M&M Sales Manager, Dar es Salaam). In the empirical discussions that follow in Chapters 6, 7 and 8, tractors and power tillers manufactured locally are not considered because they have a very limited presence on the Tanzanian market.

We now turn our attention back to the operating conditions (hereafter, OCs) delineated in the Section 5.5 and identify five situations under which the farmer is presented with a choice of technology. We discuss these OCs in turn by presenting the alternative brands from MM_1, MM_0, EE_1, and EE_0 that were found to be in use in each case and set them up for technical and engineering comparison in Chapter 7. In Chapter 6 however, the broad categories of MM and EE will be used as a framework for discussing technology transfer, diffusion and penetration.

5.6 Operating conditions (OC)

5.6.1 OC1: Power tillers on paddy fields (small scale)

Here we have power tillers preparing the soil for rice cultivation mostly on small clay fields ranging from 1 to 25 acres. These farms produce between 25 and 35 bags of paddy rice per acre per season depending on the rice variety and whether or not artificial fertilizers are applied. They are mostly irrigated and the farming system is very intensive requiring the attention of the farmer throughout the year for field maintenance, if productivity levels specified here are to be achieved. On the farms visited, Kubota (MM_0), Siam Kubota (MM_1), Greeves (EE_1) and Amec (EE_0) were the most common alternative powers. It must however be noted that Siam Kubota and Amec are the most widely used.

5.6.2 OC2: Tractors on sandy maize fields which (small/medium/large scale)

The soils here are largely sandy and light and any type of tractor, usually 25Hp and above, can work well. However, when the horsepower is lower it takes a longer period to get all the farm work completed and when the horsepower is too high there is excess capacity. Thus in relation to the farm size, there should be a balance with the horsepower chosen. Most farmers operating under these conditions have between 10 and 40 acres harvesting about 6 to 10 bags of maize per acre without soil fertility management (artificial fertilizer application) and under rain fed conditions. The farm sizes are mostly medium, though farm sizes below 10 acres and above 40 acres are not uncommon. Consequently we mostly find tractors with horsepower between 25 and 50 being used.

There are however some large farms which use machines with higher horsepower, though many of them, even if the farms are large, tend to invest in 2 or 3 tractors of the 25 to 50Hp rather than have one 80Hp tractor. Under this condition, the study will compare Farmtrac 45 from India (EE_1) with Swaraj also from India (EE_0). We shall however make reference to other MM tractors without undertaking a detailed economic analysis on them because they are usually of excess capacity under this OC, and represent a sub-optimal choice especially when we consider the common range of farm sizes. Unless owners of such large tractors have contract-hiring intentions as rural entrepreneurs, ownership of higher horsepower tractors results in low capacity utilization under this OC.

5.6.3 OC3: Tractors on Maize and Tobacco fields (medium/large scale)

Farmers under this OC are relatively wealthier than those under OC2. This is because in the case of maize, inter-cropped with vegetables and pulses, the productivity of the land is higher as a result of higher soil fertility under loam conditions. In the case of tobacco, output prices are also higher compared with maize, and the market for tobacco is relatively stable and reliable. On a per acre basis, maize farms achieve 12 to 15 bags per season. Other benefits also accrue from sunflower in the Babati area and vegetables (onion and tomato) in the Iringa area. Farm sizes here are usually medium to large scale. Here we shall compare Finish Valtra (MM_0), Brazilian MF (MM_1) and Pakistani MF (EE_1) which are in the 50 to 65Hp range. The study does not have enough data to make estimation for an EE_0 example. In this case Mahindra would have been an ideal example but its usage in Tanzania is at the infant stage, and the only sources of data were those obtained from the importers and distributors rather than from farmers. Farmers reported that they could only give a complete evaluation of the machine after about 4 to 5 years.

5.6.4 OC4: Tractors on upland rice and sugarcane (small/medium/large)

Productivity on farms here are not as high as those on OC1 especially in the case of paddy. Output per acre is about 18 bags per acre within a single season for paddy rice. The farm sizes here range from small through medium to large scale. Large scale farms (above 40 acres) are however more common than the small and medium scale ones. The common tractors used under this OC have horsepower ranging between 65 and 80, or sometimes even higher. We shall compare New Holland from UK/Italy (MM0) with MF from Brazil (MM1) and Farmtrac 70 from India (EE1).

5.6.5 OC5: Tractors on irrigated rice and sugarcane (medium/large scale)

Here productivity for both paddy and sugarcane is much higher than OC4 because of the reliable supply of water throughout the year. The soils are deep and heavy and so machines with horsepower greater than 70 are usually popular. Four Wheel Drives are preferred to prevent slipping. Rice farms produce about 25 bags of paddy per acre each season. Sugar content for sugarcane is also relatively stable during the harvesting period.

Table 5.7: Photographs of the selected machines for comparison

	Natured Markets (MM) Technologies		Emerging Economies (EE) Technologies	
	MM made in the North	MM made in the South	MM adapted to EE- made in the South	EE made in the South
OC1	Kubota-Japan	Siam Kubota- Thailand	Greaves-India	Amec-China
				
OC2			Farmtrac-45	Swaraj
				
OC3	Valmet Finland	MF-Brazil	MF- Pakistan	
				
OC4	New Holland (EU)	MF (Brazil)	Farmtrac70 (India)	
				
OC5	New Holland (EU)	New Holland (Turkey)	New Holland (India)	CATIC (China)
				

Source: Compiled from field photographs plus web-based sources dealers, 2012

Typical tractors for comparison under this OC are New Holland (Italy/UK) - MM0, New Holland (Turkey/Brazil)- MM1, New Holland (India) EE1 and YTO (China) - EE0. Other machines which could have served an equal purpose are Kubota tractors from Japan, John Deere from the US or India and Sonalika from India. But Kubota tractors are poorly supplied locally while John Deere, especially those of Indian origin and Sonalika are relatively new to the market. Table 5.7 presents pictures of the various capital goods to be compared under each of the operating conditions discussed above.

5.7 Conclusion

So far we have established that plant growth requires a good seed bed prepared with human, animal or mechanical power. When farms become commercial and there are labour constraints, mechanical power can help. Land preparation is the most common activity in which farmers are likely to mechanize. Off-farm activities like transportation and processing are also seeing significant levels of mechanisation within the sample.

Different crops grow under either rain-fed or irrigated systems. Predominant soils on non-irrigated fields are light to medium in texture. Those on irrigated fields are medium to heavy textured gradations. Three of the study regions (Dodoma as a whole and Manyera and Iringa, in part) match the rain-fed, light to medium textured soil classification. Morogoro and Mbeya fit the irrigated systems with medium to heavy textured soils. Nevertheless some parts of Iringa also fits the latter classification while at the same time some parts in Morogoro and Mbeya are found somewhere between the two extremes.

Depending on the soil type and the farm size, particular specifications of farm machinery (power tillers or tractors) are required to produce adequate draft. With adequate power the farmer can complete tillage practices on time. Good soil regimes for plant growth and development are also guaranteed if the farm power is able to break all clods and level the soil to prevent water stagnation. The size of the machine (horse power), the quality of the machine (in terms of the material used for its fabrication) and finally the technology in use (whether it is four wheel drive or not or whether the implements draw energy direct from the engine or they are pulled by the machine in motion) generally affects power tiller and tractor performance during usage.

To meet the tillage technology requirements for the different agro-economic classifications, the farmer has two broad categories of farm machinery to choose from: advanced country technologies which we classify as MM and developing country technologies, denoted EE. Machines from the two sources are not the same in character and it is this distinction in character that this study seeks to delineate, and consequently examine their effects on low income households.

To understand how distinctive these machines are, we set up a discussion in the next two chapters (using the matrix in Table 5.8), considering MM power tillers verses EE power tillers and MM tractors verses EE tractors. Under these two broad categories, the study further classifies two sub-groups. The sub-groups reflect the country of origin of soft and hard components of the technology. The study emphasises penetration levels, mode of diffusion and technical differences relating to efficiency and quality of these techniques.

Table 5.8: Analytical matrix

	Source			
	MM		EE	
Scale of technology	MM_0	MM_1	EE_1	EE_0
Power tillers				
Tractors				

MM-Matured Markets; MM_0- MM technologies made in MM; MM_1- MM technologies made in EE
EE- Emerging Markets; EE_1-MM technologies adapted to EE; EE_0- EE technologies made in EE

Source: Generated by author, 2013

Chapter 6 : Technology Transfer, Diffusion and Penetration

6.1 Introduction

In a perfectly competitive capital goods market, different dealers (importers and distributors of power tillers and tractors) are expected to interact with manufacturers to respond to user needs. In this competitive world, there is a general assumption of the existence of perfect knowledge: importers know the needs of the users and the users in turn know the characteristics of the capital goods. Thus, by liaising between manufacturers and users, importers balance supply both in terms of quality and quantity. Farmer demand for capital goods with a peculiar bundle of features is influenced by their own characteristics embedded in farm size, soils and farming systems. The financial position of the farmer cannot be overlooked. That is, for farmers to access these capital goods, they need money. These financial resources can be generated from the farm business through savings or sourced from elsewhere.

In instances when the farmer cannot find the capital themselves, some form of financial intermediation is required. Thus financial institutions such as commercial banks, cooperatives and money lenders are also important in this process of technology transfer. At the very least, importers of power tillers and tractors will require some form of financing, especially if manufacturers do not advance stocks on credit. Even if they did, other expenses for transporting and clearing the goods from the port must be paid for. As we shall see in this Chapter, the need for financing the technology transfer process at the importer; distributor; and farmer level is key, and requires innovative ways especially in a capital constrained country like Tanzania to make it successful.

Government agencies are also expected to protect the interests of importers and users by playing a refereeing role that ensures markets operate effectively and standards are maintained. In this instance product standards rather than process standards are very important (Kaplinsky, 2010). We argue in this chapter that either by design or circumstance, central government participation in the tractor technology transfer process has not always allowed for a free market environment. For a large part of the tractor technology transfer history of Tanzania; central government has been very active. The consequences of being a player and a referee cannot be over emphasized. This status quo is however changing with time.

This chapter builds on the foregoing arguments by discussing the technology transfer process from the two main sources delineated in chapter 6, (MM and EE) and the associated transaction costs. An attempt is then made to characterize the distribution networks which importers use to promote the technologies, emphasizing the strategies adopted by government and private sector actors and the signals transmitted by manufacturers and users within the system. We also examine the level of penetration of MM and EE machines in the framework of small machines (power tillers) and large ones (tractors) nationwide and within the sampled farms. Activities of the machinery testing unit in the country and how it is affecting the value chain is then presented. Before the chapter is concluded, the sources of finance and the costs associated with them as farmers purchase capital goods are also discussed.

6.2 Mode of technology transfer and diffusion

There are three general ways through which technology can be transferred from one country to another: aid, trade and foreign direct investment. Licencing is also noted as a fourth channel (as a form of FDI) (See Chapter 3). These modes are however not mutually exclusive. When the technology has arrived in the destination country, a network of distributional infrastructure or system is then required. These processes of transfer and diffusion of technology can be systematically planned and executed. In other instances, the process is not planned. The process may evolve depending on how actors in the system respond to supply and demand forces. In the case of Tanzania, with reference to power tillers and tractors from MM and EE sources, each of the three modes of technology transfer (aid, trade and FDI) have played different roles to different extents in making MM and EE technologies available on the market and farms. In this sub-section, we describe these modes in a historical perspective and the extent to which they have varied over time and space.

6.2.1 Tractors

Four wheeled farm tractors have been in use on Tanzanian farms since the second half of the 20th century. Throughout the last six decades, the trajectory of technology transfer strategies can be classified into two waves: pre- and post- the Structural Adjustment Programme (SAP). Before the 1990s, decisions on whether to import tractors or to produce them locally was centrally planned and controlled by government agencies, with little emphases on private sector participation. At best private sector participants were agents of the government, if they were given any role at all. However, during the structural adjustment period, the emphases shifted from state led activities to private sector led growth with central government only facilitating the process. Here we discuss the role that aid, trade and FDI has played in transferring tractor technologies from MM and EE sources into Tanzania.

a. Aid

The aid landscape for tractor imports was dominated by Japan during the pre-SAP days. In the 1970s and 1980s, the Japanese development agency, JICA, assisted the Tanzanian government to develop the Lower Moshi Irrigation Scheme[20]. As part of this project the Japanese also made available to the Tanzanian government about 400 Kubota tractors over the period (Key informant interview the director of KATC, 2012). Though the quantities of such gifts have declined in number over the years, the Kilimanjaro Agricultural Training Centre[21] continues to benefit from such aid arrangements. These tractors given to Tanzania through aid are of the MM classification and are very robust. After several years of use, most of these Kubota tractors were

[20] This is a rice irrigation scheme managed by farmers with government assistance in the Moshi area

[21] It is an institution set up through collaboration between the Tanzanian and Japanese governments to provide short term training for extension workers in the production of paddy rice.

auctioned by government to farmers. Most of the farmers are still using those tractors today, though spare parts are difficult to find.

In recent years, 2009 to 2012, India has become the main source of aid to Tanzania in terms of the importation of tractors. There is however some difference between the Japanese and Indian aid. While the Japanese aid was a gift and they specified the kind of equipment they gave as a gift, the Indians gave the Tanzanian government a soft loan and allowed them to use it to import any tractor they considered appropriate for their situation and purpose from India. Thus the Indian aid had some level of flexibility and responsibility attached to it. First because the choice of technique was only constrained by the country of origin, but not the quality, cost and scale. Second, because the Tanzanians were going to pay back the loan, they had to develop a strategy that would ensure that farmers who took the machines could make good use of them and pay back within a specified time frame. We therefore see a gradual shift from aid as charity, as in the case of the Japanese, to the development of commercial entrepreneurs in the Indian case.

b. Trade

In the 1950s, prior to independence, foreign owned private commercial farms were the main importers of tractors; mainly to cultivate cash crops like tea, coffee, sisal, tobacco and wheat. After independence, in the early 1960s, commercial Tanzanian farmers of medium to large scale used tractors to cultivate maize in Iringa, wheat in Arusha and Cotton in Shinyanga. These farmers were encouraged by the newly independent government through easy access to land and the fact that they could either buy second hand tractors from foreign commercial farmers or import units from abroad on their own. In addition to access to credit from cooperatives, the national development credit agency and a few private tractor dealers on the local market also helped farmers in obtaining imported tractors (Key informant interview with operations manager of the AITF, 2012). With most of these settler farmers being European and as an example to the emerging local farmers, almost all of the tractors used then were from Europe (MM). In addition, tractor manufacture in India and Asia in general (apart from in Japan), was at the infant stages, and just entering the second decade of production. Direct participation by the Tanzanian government was minimal in the process of importation of tractors at this time.

Between 1965 and 1970, central government took an active role in importing and distributing tractors to state farms and village development block farming schemes. Both MM and EE machines were imported, though the EE ones were very few. Generally, most state farms imported MM machines directly from the manufacturer or through local agents. Friendship farms (mainly developed by the Chinese for Tanzania) imported EE tractors from China.

The period between 1970 and 1984 saw the Tanzanian government becoming the sole importer of tractors and they did so mainly through trade. Most of the imports undertaken by government then were from MM sources (Great Britain, Japan, USA and Germany). A few tractors were however imported from EE sources mainly India.

Post structural adjustment trade and imports of tractors saw reduced central government participation. However in cases when government participated, the machines imported were mainly from India. A typical example is the Escort brand of tractor imported from India through government assistance and sold to farmers in the 1990s. During this period new tractor companies were registered and companies dealing in other vehicles opened tractor departments. While some of the old companies continued to import MM brands, the new participants typically with Tanzanian-Indian owners, concentrated on importing EE brands from India. Other companies which had previously folded up re-entered the market; a case in point is Hughes Motors in Arusha.

c. FDI

In 1985, imports of tractors from abroad into Tanzania were stopped. This was in conformity with an import substitution strategy adopted by the country. The Tanzania

Tractor Manufacturing Assembly Plant (TRAMA) was set up in 1982 as a joint venture between the State Motor Corporation and the Valmet Tractor Company of Finland. Valmet by our broad categorization is an MM tractor. The share capital of the Tanzanian government was 90% and the remaining 10% was held by the Finish Company. The production of Valmet tractors at the plant started in 1983. Between 1983 and 1989, the company produced a total of about 2,300 tractors, peaking in 1985 at 730 units a year. In the first two years, the company assembled parts imported from Finland. In the ensuing years, it started to incorporate locally made parts into tractors.

With the country returning to a free market economy in the 1990s, and demand for tractors (estimated at 1,500 to 2,000 per annum) outstripping Valmet's Tanzania based plant's ability to supply (of about 300 to 700 units per annum), other private companies were allowed to import tractors again (TRAMA, 1989). In 1995, Valmet had stopped tractor production altogether, since those imported were cheaper and arguably much more reliable. Since, then the country has yet to see another foreign direct investment that targets the local assembly or production of tractors. There have however been discussions in 2011 by M&M Tractors, an Indian company, to start the assembly of Mahindra Tractors in the country.

Thus while the pre-SAP period witnessed FDI as a significant player in the tractor technology transfer in Tanzania, the post-SAP period has seen very little cross country partnerships to produce tractors locally. We observe trade playing a key role in the technology transfer process in both the pre- and post-SAP periods. Today, more than 7 out of every 10 tractors in the country came in through open market transactions. Non-governmental organizations like churches importing tractors for their farms mainly target MM sources through trade. Aid is also important and we also find FDI contributing to the process of technology transfer especially during the pre-SAP days. See Table 6.1 for a summary.

Table 6.1: Tabular summary of mode of tractor technology transfer: Aid, Trade & FDI

Period	Actors	MM			EE		
		Aid	Trade	FDI	Aid	Trade	FDI
Pre-SAP	Government						
	Non-government						
	Private sector						
Post-SAP	Government						
	Non-government						
	Private sector						

Source: Generated by author, 2012

6.2.2 Power Tillers

The importation and distribution, as well as local manufacture of power tillers in Tanzania have witnessed government, non-governmental and private sector participation in the past and present. While central, regional and local government efforts have been propelled by either a coordinated effort to push sectoral policies, or fulfilling campaign promises, and in some cases the need to use aid receipts visibly, the private sector participants are usually driven by Schumpeterian reasons underpinned by profit making. These actors sometimes go beyond distributing power tillers. They also train farmers on power tillers usage and how they can manage their fields to get the full benefits from the machine. While local manufacture of power tillers is still in its infancy, the few produced so far are pushed by private firms who have profit motives. It was only in the 2000s, that power tillers became a significant part of the farm mechanisation technology mix for Tanzanians; before then, hand hoe, animal power and tractors were commonplace.

a. Aid and government support

Of the three main actors engaged in farm mechanisation technology transfer in Tanzania, government was initially the main actor using aid as a tool for importing power tillers. At the onset, government bilateral initiatives in the first half of the 2000s were associated with high quality, durable and efficient power tillers of MM origin (Japan and South Korea). Thus between 2001 and 2003, Tanzanian government multi-lateral cooperation with the USA and Japan and bilateral agreements with South Korea resulted in the importation of high quality Kubota power tillers from Japan as well as Kukje and

Daedong power tillers from Korea. These power tillers were distributed to farmers under a subsidy at about half the actual price (Key informant interview with a retired mechanisation expert in Morogoro, 2012).

In 2009 and 2010, using a grant from the Indian government, the Tanzanian government imported Greaves power tillers (an EE category) from India through Noble Motors Company Limited and Suma JKT[22]. These power tillers are of intermediate quality and durability. Thus while in the early years, central government aid agreements centred on high quality and high cost power tillers, we see a shift towards relatively lower cost and lower quality ones with emphasis on cheaper capital goods in order to share the benefits between as many farmers as possible. Occasionally, aid agencies like DFID imported and distributed power tillers to farmers through aid. The private sector has rarely been involved in aid as a tool for the importation of power tillers. Thus while the pre-2005 imports through aid targeted MM machines (from Japan and Korea); the post 2005 importations were from EE (specifically India). Chinese power tillers have not been involved in aid during the period under consideration. It is evident, at least in the instances discussed here that the source of power tillers transferred to Tanzania through bilateral or multilateral aid receipts depends more on the source of the aid, and not necessarily what is fit for purpose.

b. Trade

Trade is by far the most important mode of power tiller technology transfer. Estimates by experts in the field suggest that it could account for more than 80% of total imports. The private sector is the main actor using this mode. Their emergence was in response to a latent demand created at the end of government collaborations with the American, Japanese and Korean governments. The private sector began importing low quality, low cost machines from EE (mainly China, and sometimes India), in significant volumes after

[22] Suma JKT is an arm of the Tanzanian military engaged in trading in the country. The Tanzanian government sourced a loan of $50m from India. The money was advanced to Suma-JKT to procure and import 1868 tractors and about 400 power tillers from India in the year 2010.

2003. The main objective of the private businessmen and women then was to create access to power tillers which would undercut the ones imported and subsidized by government in terms of pricing, and also overcome some of the challenges faced by MM machines such as availability of spare parts (Key informant interview with an importer of power tillers in Dar es Salaam, 2012).

The private businessmen and women envisaged that without government subsidies, resource constrained peasants could not afford the Japanese and South Korean brands. In addition, dealership rights from Kubota, Daedong and Kukje were difficult to obtain compared with Chinese manufacturers. Furthermore, Kubota especially would not advance stocks until full payments are made for every product in a consignment. Dealers acknowledged the high quality of MM products, but the size of their business capital and the characteristics of the markets (farmers) did not encourage this technology source.

The most common brand which dominated this wave of imports, and continues to dominate the power tiller landscape in Tanzania today is the Amec power tiller from China. One prominent importer and distributor, Auto Sokoini Limited led the importation and marketing of the Amec brand. In the past ten years both the company and the brand have become household names. Auto Sokoini Limited has been in the agricultural machinery (especially small shelling machines) business since the 1990s. The company secured the distribution rights from Changzhou Agricultural Machinery and Equipment Ltd of China (AMECCO). Auto Sokoini Limited had been in business with AMECCO since the early 1990s. With the privatization of AMECCO in the 1990s in China, new management wanted to diversify by moving into the production of small diesel engine tractors and generators. Auto Sokoini found itself in a market where the demand existed for such capital goods, but supply was very low. The main Japanese sources were at that time unwilling to give distribution rights to local dealers. As in the words of one leading industry informant,

> "...they (the Japanese) were afraid of counterfeits and they were not also willing to give their technology out on a silver platter" (Source: Field interviews, 2012).

This link with AMECCO by Auto Sokoini encouraged other businesses to import various brands of power tillers from China. Most of these brands had spare parts which could be cannibalized for others from the same country. In addition, some private importers transferred JST Shakti power tillers from India to Tanzania during the same period. The Indian machines were generally of higher quality and higher cost, compared with the Chinese ones, though these specifications were lower quality compared with the Korean and Japanese machines.

Since 2006, though Amec's prominence has not declined, some traders imported relatively higher quality machines from Thailand (Siam Kubota). The Siam Kubota is not as robust as Kubota, Daedong or Kukje, but better than Amec and JST Shakti. It is produced by the Kubota Company in collaboration with Siam Cement Company in Thailand. It is a reduced form of the Kubota power tiller with some of the original features simplified. The manufacturing process has also been made more labour intensive, compared with what is produced in Japanese plants where production is highly automated and robots do most of the assembly. With this arrangement, it became easier for Farm Equip Limited, a Tanzanian company to obtain the dealership rights for these power tillers from Thailand. Thus presently, it competes with Amec on the Tanzanian market. Other brands from India are not in keen competition because of the numbers supplied.

In 2009 the government legislated that each district in the country should procure between 20 and 50 power tillers and subsequently make them available to farmer groups on a credit basis. To respond to this demand, the private sector operators who won the bid to supply these power tillers mainly imported EE ones from China. Specifically Chinese brands like the Changfa and Dongfeng have been the most popular under this programme.

c. FDI

Partnerships and Transnational Co-operations manufacturing power tillers in Tanzania is non-existent. Power tillers are generally used on small farms, ranging from an acre to about ten acres in size. Investors coming from outside of Tanzania will do not operate on such small scales usually preferring to invest in large scale commercial farming operations. FDI features less as a mode of transferring power tiller technologies from any of our two main sources, MM and EE. However, one commercial farm controlled by Indian investors is known to import power tillers from China to be distributed to out-growers on their scheme. Apart from this case, foreigners participating in food production in Tanzania rarely import walk-behind tractors for use on their farms.

Table 6.2 gives an idea of the different actors and the modes of technology transfer they have used to import power tillers from MM and EE sources and how it is changing over time. Trade dominates the mode of imports, followed by aid, with FDI rarely playing a role. Of all the power tillers in use in Tanzania today, more than 90% were brought in through trade by the private sector.

Table 6.2: Tabular summary of mode of power tiller technology transfer: aid & government support, Trade and FDI

Period	Actors	MM			EE		
		Aid	Trade	FDI	Aid	Trade	FDI
2000 to 2005	Government						
	Non-government						
	Private sector						
2006 to 2011	Government						
	Non-government						
	Private sector						

Source: Author, 2012

On the whole, the search by both private and public institutions for an optimal kind of power tiller for the Tanzanian market has followed different paths. There is however evidence from casual empiricism to suggest that government, non-government and private sector actors are converging in terms of choice of technique since the latter part of the 2000s. While government initially begun with aid as a main tool of importation (concentrating on MM machines), today it is involved in a bundle of both aid and trade emphasizing intermediate techniques whose quality and cost lie between MM and EE specifications. What remains unchanged is the use of financial instruments (subsidies) to make technologies more accessible to resource constrained farmers. Private businesses on the other hand have used trade over the entire period, starting off with low quality and low cost machines. Presently, power tillers imported through trade by the private sector encourages medium quality and cost, though low quality and low cost machines continue to dominate the market. FDI as a means of technology transfer is generally negligible or non-existent.

The patterns observed here in terms of time line and phasing are similar to experiences in other Asian countries like Bangladesh where the use of power tillers is quite popular. First, high quality Japanese power tillers are promoted through aid. Private sector dealers observe the interest of users and also acknowledge their purchasing power and bring power tillers from China which is relatively cheaper (50% of the Japanese prices). These are then followed by Korean machines, but in relatively small quantities. The quantity of machines brought in from China is expanded and then finally other suppliers from India and elsewhere including China are introduced into the country. (Biggs et al., 2002)

6.3 Importer, distributer and farmer linkages

There are over 40 companies currently importing and distributing agricultural machinery (including power tillers and tractors) in Tanzania. Of these, 12 are very active in terms of quantities imported. The head offices of these companies are mostly concentrated in Dar es Salaam, the economic capital, and some in Arusha, an important trading and agricultural centre in the northern part of the country. There are also a few companies head-quartered in Morogoro, a region singled out as the grain basket of the country and Tanga, in the north eastern part of the country. While some of these companies have metamorphosed from state owned enterprises after the inception of SAP into privatized firms; others are private companies which have existed for several years.

In recent years, some companies have also sprung up in response to the national mechanisation drive. There are two main types of companies undertaking the business of importing and distribution of tractors. The first small group consist of those whose main business is farm machinery only. The second group is made up of companies engaged in the dealership of general automobiles and have departments responsible for tractors and power tillers. There is however a third category which has strong government support and linkage: Suma JKT, an arm of Tanzanian military which has been involved in the bulk import and distribution of tractors since 2010. However, Suma JKT's presence on the tractor market is unlikely to continue when the government grant they are operating with runs out. Generally, older companies participating in the Tanzanian tractor market have a higher tendency to import from MM sources, whiles newer firms are more EE oriented.

The three categories of companies described above have networks of dealers across the country. The older companies have their own sales centres in Tanzanian cities; the newer and younger firms usually form alliances with already existing businessmen and women who are interested in selling their products. Suma JKT on the other hand adopts both market structures having its own sales centres and alliances with interested distributors across the country.

Worthy of note is another group of companies, mainly family businesses which specialise in the importation of spare parts for various brands of power tillers and tractors from both MM and EE sources. Such companies are usually located close to the farming centres so that farmers can reach them easily. They also have a network across the regions and some of them have been operating for more than three decades. It is a requirement by the Tanzanian regulatory framework for all licensed importers to have a minimum number of distribution networks to facilitate after sales services. However, such infrastructure is poorly developed. Dealers argue that it is difficult to comply with this requirement. They argue that the levels of demand are not high enough to provide a critical mass that will support sales and service centres in each region. In the words of one dealer:

> "…the highest number of tractors and power tillers I have sold in a year is 60, coming to an average of 2 per region across Tanzania. Imagine I had a sales and service centre in those regions, it would be impossible to finance the housing, labour and taxes associated with it. That is why we ask the owners and users to give us a call when there is a problem; then we can dispatch technicians in a day or two to handle it for them" (Key informant interview with a marketing and sales manager of a tractor importing company in Dar es Salaam, 2012).

Generally, sales agents and service centres for MM power tillers are fewer than those trading in EE power tillers, mainly because of the capital requirements. Nevertheless for tractors, it is easier to get access to spare parts for MM machines than the EE ones because of the long standing presence of the MM dealers. The opposite is true for the power tillers: access to spare parts for MM brands is very difficult, because the distributors are fewer and the imports are also low. The power tiller units from EE sources and their spare parts are ubiquitous because there are many distributors spread across several districts and communities. In addition spare parts for different brands from China can fit one another. MM importers are most often prepared to give tractors and power tillers to distributors without having to make full payments on condition that the distributors' premises are insured and able to provide the technicians who can give after sales service.

These requirements make it difficult for medium sized distributors across the districts to have the capacity to distribute these machines. To get around this problem, especially in the case of MM power tillers, the importers work together with co-operative societies across the regions which can facilitate the bulk purchase by members through loans secured from commercial banks. Such loans are sometimes taken from SCCULT, an umbrella group of all cooperatives in the country. In this way, the importer is able to deliver in bulk a number of power tillers to the co-operative group for onward distribution to interested members.

The difficulties associated with securing a right to distribute MM tractors, is making them quite unpopular of late. Thus most of the buyers nowadays are very large scale commercial farms. The only exception is one company in Morogoro which sells second hand MM machines which has over the years created a relationship with farmers that allows them to import machines based on what the farmer specifies.

The case of EE tractors and power tillers is quite different. For the tractors, the importers either establish a full sales centre in the district where demand is highest or form a strong alliance with already existing distributors of other brands. A case in point for the former is Swaraj Company in Kibaigwa in the Dodoma region. An example of the latter is Agripak Tanzania Ltd which imports Massey Ferguson tractors from Pakistan[23]. The company operates a central depot in Tanga but with 3 networks in the regions where they are particularly active (that is Iringa, Morogoro and Dodoma).

In the specific case of EE power tillers, it is essential to emphasize that except for those facilitated by government importation; very few of them are sold on credit. Thus distributors generally buy them with cash at wholesale prices in Dar es Salaam and bring them into their districts (localities) for onward sales to the farmer. Another informal, but significant arrangement through which local dealers sell EE power tillers to farmers is to give them out on credit without any down-payment just before the cropping season starts. This arrangement is undertaken in the hope that at the end of the season the farmer will pay with proceeds from his/her harvest. It is typical for small scale paddy

[23] These tractors came into Tanzania between 2009 and 2010. The machines breakdown often especially in areas where the soil is heavy. Recently a delegation from the company in Pakistan visited Tanzania to take soil samples that will be used for improving machine quality through laboratory tests (Key informant interview with a spare parts dealer in Morogoro, 2012)

farmers to access this facility. In addition to this, the main importer, Auto Sokoini Ltd, has representation in 5 regions and has plans to expand in the near future to others.

6.4 Dealers' transactions costs

In a capital constrained environment where farmers wanting to buy capital goods are mostly poor, attempts to curtail auxiliary costs in the marketing and distribution of products is important. Distributors pass on all transaction costs to buyers. Thus examining the sources of additional costs could serve as a first step for cost minimization as an attempt is made to create access for the poor. There are six main costs associated with the importation, marketing and distribution of power tillers and tractors in Tanzania: transportation and duties; warehousing; advertisements; and servicing (in the case of machines sold under warranty); testing and certification in the case of new model introduction; and management and other auxiliary labour costs.

The costs of transportation are twofold. First is the cost of shipping from the country of origin and second is the cost of transporting the machine from the point of sale to the farmers' farm. Companies importing power tillers and tractors generally agree that it is more expensive to transport them from MM than from the EE, with the exception of Japan and Korea. On average, a 40 foot container filled with tractors from Europe, America or Brazil costs about $8,000 to $10,000 to transport and takes an average of 4 to 6 weeks to arrive in Tanzania. A similar container from Asia on average costs $4,000 to $6,000 to transport and arrives within 3 to 4 weeks after it has been dispatched. Another difference between the two sources is the fact that MM suppliers always have stocks, and so as soon as an order is made, it can be dispatched.

The EE markets rarely keep inventory and they will only produce when an order is made. The fact that EE manufacturers only produce when an order is placed means that it can take up to a month or two before a consignment is dispatched especially if it is a complete tractor unit or a spare part which is not very common. This automatically evens out the time lags.

In terms of local transport within Tanzania, farmers who buy their equipment through loans have it delivered to their homes or in some cases a central point in their village and the cost is worked into the acquisition cost. Farmers buying machines with cash from importers, distributors or local dealers have to make their own transportation arrangements and this can cost up to an additional 2% of the value of the equipment (Survey data, 2012). Other costs associated with local transportation are the risks associated with highway accidents which can cause machinery damage beyond repairs. In the absence of insurance to cover goods in transit, the dealer bears the total cost of such damages. EE distributors are usually susceptible to this risk, since the importers rarely take charge of such transport arrangements.

On the issue of duties and taxes, agricultural machinery in Tanzania is import duty and VAT exempt. In addition, spare parts worth 10% of each tractor or power tiller imported are also duty and VAT free (at the time of writing this thesis). Though importers are generally comfortable with port arrangements in Tanzania, some asserted that they have recently noticed long delays in clearing their goods. Specifically they refer to the time when import and VAT duties were lifted from agricultural machinery. The impact of these delays on the importer is the need to pay for housing of their consignment at the port for as long as it is not cleared. They argue further that when the goods stay in the port for a long time, the accumulated housing fees take a chunk of the benefits they derive from the tax exemption and they have no other means of recouping that money than to pass it onto the farmer.

Warehousing and office spaces costs are not necessarily dependent on the origin of the machine. There are however higher risks associated with losing more expensive machines to theft or fire outbreaks from MM sources than those coming from EE. Thus insurance for more expensive machines in storage are consequently higher because they are computed on the basis of their market value.

Advertising is also a crucial aspect of the job of importers and distributors and requires labour and capital. The main modes of advertising by importers and distributors are through television, radio, newspapers and brochures. Some companies also engage in active campaigns moving from village to village to speak with farmers about what they have in stock for sale on market days. Another important mode of advertising is through national agricultural and industrial exhibition shows. Throughout the period of this research, I found that intensity of advertisement by newer firms dealing in EE machines was higher than MM ones and their presence at two national exhibitions I attended were very visible. It was clear that to compete with the already established MM brands, they had to do more in terms of making farmers aware of what they stood to gain if they bought from them as first time tractor owners, or switched over, if they are already used to an MM brand. Older companies selling household brands barely advertised. Some distributors give conservative estimates of advertising costs as being about 1% of the value of each machine sold but also stated that this falls as the brand and model becomes popular among users.

Usually when new machines are sold, the seller gives a warranty of between one and two years. This warrant entitles the buyer to full repair and replacement of parts at no fee if there is a problem with the machine within the period. However technicians would have to establish that such a breakdown is as a result of factory defect and not user negligence. Both tractors and power tillers of MM origin have this kind of warranty in Tanzania. However, though tractors of EE origin have warranty, the power tillers do not always have it. Thus, for Amec users for instance, if there is an engine failure in the first year, they have to bear the full cost of repair and spare parts replacements. Though importers and distributers see meeting the demands of warranty as an important cost, several users who have had to make claims said the service support usually comes too late and the farmer would have already found and paid for a solution.

A final but controversial cost associated with the import of a new model is testing of the machine to ensure that it meets the minimum safety and quality standards as specified by Tanzanian law. CAMATEC is a government agency situated in Arusha charged with testing agricultural machinery including tractors and power tillers. The controversy arises from the fact that even though such testing is required by law, it is not being enforced and the certificate is only required when the importer wants to participate in a government procurement tender or bid. Thus the basic tenet of the law to safeguard the interest of farmers is not enforced. While some importers go through the laborious and expensive process of having to give one unit of the new model they intend to import to the testing agency and paying for the fuel and spare parts as the testing is carried out for about 6 months to one year, others do not. It has, in effect become voluntary. The results of such tests are rarely published and so farmers do not get the opportunity to make a choice based on such information.

Officials at the testing agency however mentioned that importers of the MM machines usually comply with the testing requirement and even generally incorporate any changes or improvements required as specified by the test report. There are five testing officers at the agency. All five obtained their testing training from Japanese Institutions. This thus leaves the question of whether they are suitably equipped enough to test machines manufactured outside Japan, especially Indian and Chinese machines in the face of changing technology and a world where cost innovation may sometimes mean concealing the effects of some reduction in material quality or other more detailed processes such as hardening of metals.

6.5 Penetration and extent of use

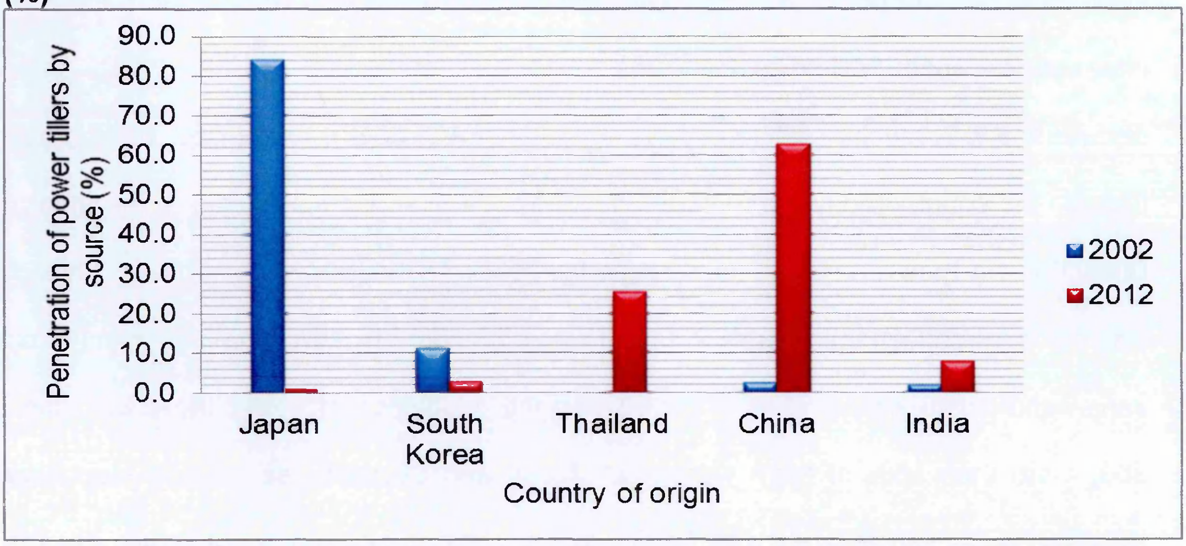
Depending on the interaction between supply and demand factors, different technologies are diffused to varying extents across and within regions. While profitability in use, access and availability of particular technologies at any one point in time may explain why they get diffused, sectoral policies by central government also affect the nature and extent of diffusion. In the case of Tanzania, as clearly mentioned in Chapter 1, MM machines dominated the market between 1950 and 2000. Thus MM machines were the main capital goods which were popular among farmers then. However, in the 2000s there were new entrants from the EE in significant quantities. In this section the level of penetration of technologies from the two sources (MM and EE) is examined. The discussion is undertaken with reference to the pre-SAP and post-SAP periods for tractors; and before and after 2005 for power tillers, using a snap shot for each reference period.

6.5.1 National level penetration of power tillers

With less than 100 power tillers on Tanzanian farms in the year 2000, their population increased by about 50 fold reaching the 5,000 mark at the end of 2012 (Focus group discussions with mechanisation experts at the MOFAC, 2012). About 25% of all power tillers in the country today are found in the Mbeya Region and specifically in the Mbarali District where they are mainly used on paddy fields. At the onset, when the technology was being introduced in the early 2000s, it was dominated by MM machines mainly from Japan and South Korea. Thus in 2002 when the population of power tillers was about 350, more than 95% of them were from Japan and South Korea with the Japanese Kubota dominating the landscape. During this time the Kubota power tillers were evenly spread across several districts in the country. The most popular South Korean brand then was the Kukje, which was mainly concentrated in the Morogoro Region. At the time, there were few EE power tillers, representing less than 5% of the entire population. The common EE brand then was Amec from China with negligible numbers of JST Shakti from India (Key informant interviews with deputy director at the mechanisation department, 2012).

In the ensuing years, the number of Kubota and Kukje power tillers stagnated, and their proportion in the population diminished. Other brands like Daedong from South Korea were introduced, but did not gain much prominence. The number and proportion of EE machines, especially Amec, continued to rise overtaking the MM brands in 2004. Other brands like JST Shakti from India continued to grow albeit slowly. The introduction of Siam Kubota in 2007 (from Thailand), a reduced from of the Japanese Kubota, also gained some popularity among farmers who were members of cooperatives. It did not however gain as much momentum as the Amec. At the end of 2012, the picture had changed with seven out of every ten power tillers coming from an EE source. Figure 6.1 gives a snapshot of the population dynamics of power tillers in 2002 and 2012 by their country of origin.

Figure 6.1: Penetration of power tillers in Tanzania by country of origin, 2002/2012 (%)

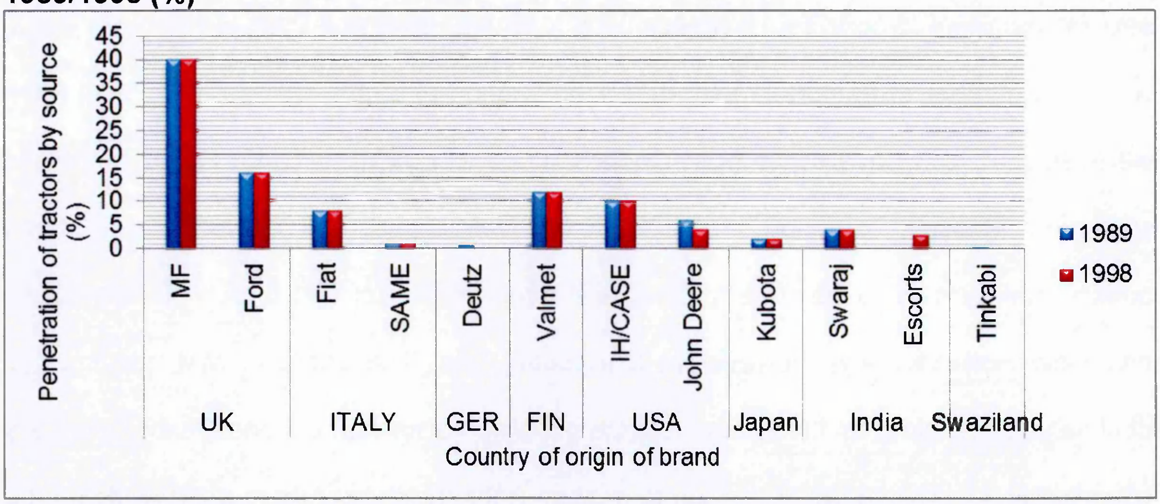


Source: Key informant interviews at the Mechanisation Department of The Ministry of Food, Agriculture and Cooperatives, 2012

6.5.2 National level penetration of tractors

Between 1989 and 1998, the brands of tractors which dominated the Tanzanian farming landscape did not change much. Over the period, more than 95% of all tractors in use had MM origins. MF and Ford from the UK and Valmet from Finland constituted more than 65% of the entire population. CASE and John Deere from the USA were also important constituting about 15% of the population. Other MM brands were Fiat, SAME, Deutz and Kubota. The odd one out then was Swaraj, the only EE brand from India representing about 4% over the period. Thus key brands on the market were from Europe, USA or Japan in the 1990s (Mpanduji, 2000). See Figure 6.2.

Figure 6.2: Penetration of tractor brands in Tanzania by country of origin, 1989/1998 (%)



Source: Ministry of Agriculture, Livestock Development and Cooperatives, 1991/1999; Clarke, 2008

With the production of MF, Ford and Fiat curtailed in Europe, the importation of both brand-new and second-hand versions of these brands into Tanzania stalled in the 2000s. Production centres of MF and Valmet moved to South America, specifically Brazil and Argentina. Trade relations between Brazil and Tanzania were not very developed then, and so over time importation of such brands were also curtailed. American farms also grew in size, consequently CASE and John Deere products also became bigger in scale, making them unattractive for the relatively smaller farm sizes in Tanzania.

What finally triggered a gradual shift in the choice of technique was the opening of plants by New Holland (as a result of Ford/Fiat/New Holland merger) in Turkey and India and by John Deere in India and China. In addition, some companies like Massey Ferguson also licensed plants in Pakistan and India to use their technology and in some cases also their trade names. Though not openly accepted by manufacturers under such licensing arrangements, distributors and users observe that the quality of products from these newer production plants in EEs is not as high as those from their original plants in Europe. In addition, traditional brands in India like Escorts also expanded output and consequently exports. Mahindra, a very popular brand in India is however yet to gain any real footing in the Tanzanian market.

These developments, together with cost innovation coming from the EE sources led several importers to consider doing business in China, India and Pakistan. Thus in 2011, when the number of tractors in use in Tanzania stood at 8,466, more than 35% of them were estimated to have come from China, India and Pakistan. Today some of the old stocks of Massey Ferguson, Ford, Fiat and Valmet are still operating and some commercial farms also continue to procure the new makes of CASE, John Deere (USA) and New Holland (Italy), however at a reducing rate. The share of MM machines is diminishing over time as farms now replace old MM stocks with EE ones, except for very large farms whose orientation are yet to change (though some of them are now doing the number crunching in terms of what is profitable). Emphases is now being placed on EE machines and this emphases was given a further boost in 2009 and 2010 when central government assisted the importation of 1,486 units of Farmtrac tractors and about 400 units of New Holland tractors, all from India.

6.5.3 Penetration of power tillers within study sites

Power tillers in the study area in the case of MM were dominated by Siam Kubota from Thailand and for EE by Amec. This finding generally mimics the national situation, in which the dominance of EE power tillers; specifically Amec was evident in the previous section. This provides evidence that different technology trajectories dominate the stage at different times. See Table 6.3.

Table 6.3: Power tiller utilization across study sites

Source	Category	Country of origin	Brand name	Frequency	Percent
MM	MM_0	Japan	Kubota	4	4.21
	MM_1	Thailand	Siam Kubota	32	33.68
EE	EE_1	India	Greaves	3	3.21
	EE_0	China	Amec	57	59.00
Total				95	100

Source: Field Work, 2012/2013

6.5.4 Penetration of tractors within study sites

The distribution of tractor makes across the study sites is shown Table 6.4. MM machines are dominated by Ford, MF and New Holland. There are two main countries from which Tanzania imports EE tractors: India and Pakistan. The most common brands from these two countries dominating our sample are Swaraj, Farmtrac and Massey Ferguson. There are more brands coming from India than from China. It must however be mentioned that there are other brands like YTO, KAMA and Europard which originate from China but these are yet to gain the popularity possessed by those from India and Pakistan.

Table 6.4: Tractor brands within sample by country of origin (Frequency and Percent)

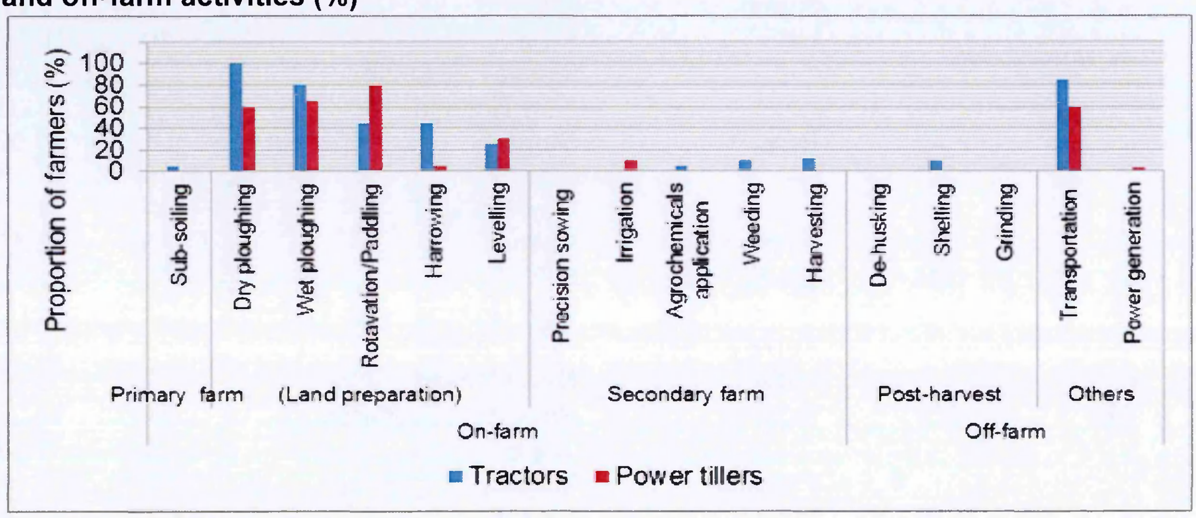
Broad category	Detailed category	Country of origin	Brand name	Frequency	Percent
MM	MM_0	USA	IH/CASE	3	3.06
		Japan	Kubota	2	2.04
		UK	Ford	10	10.20
			Massey Ferguson	8	8.16
			New Holland	1	1.02
		Italy	Same	1	1.02
			Fiat	7	7.14
			New Holland	1	1.02
		Finland	Valmet	5	5.10
	MM_1	Brazil	MF	1	1.02
			New Holland	1	1.02
		Turkey	New Holland	4	4.08
		India	New Holland	3	3.06
EE	EE_1	India	Powertrac/Farmtrac	14	14.28
			TAFE	1	1.02
		Pakistan	Massey Fergusson	9	9.18
	EE_0	India	Swaraj	24	24.49
			Escort	3	3.06
Total				98	100

Source: Field Work, 2012/2013

6.5.5 Extent of use: a micro level discussion

In Chapter 5 we established that though power tillers and tractors can be used for primary, secondary, post-harvest and off farm-activities, farmers rarely achieve full capacity utilization. We noted that most users of power tillers and tractors concentrate on land preparation activities and in some cases transportation of farm produce (The World Bank, 2012). We also mentioned that in communities which are not connected to the national electricity grid, some owners generate power with their tillage equipment by connecting them to dynamos. Field maintenance, plant protection and post-harvest practices are on the low side in terms of tractor and power tiller use. Figure 6.3 gives an idea of the proportion of farmers in our sample using their machines for various farm activities. This was generally consistent across regions. Across regions, the activities for which farmers use their machines for do not differ significantly. There is a difference however, in the way farmers with different crop types use the machines - maize farms mostly use their tractors for dry ploughing. On sugar cane farms, the machines are mostly used for sub-soiling and wet ploughing. Rice farms used them for ploughing and rotavating whilst tobacco farms typically used the tractors for dry ploughing and harrowing

Figure 6.3: Respondents using their tractors and power tillers for various on-farm and off-farm activities (%)[24]



Source: Field Work, 2012/2013

[24] In total the sample size is 193 (95 power tiller owners and 98 tractor owners)

For the purposes of land preparation, MM and EE machines can perform to varying degrees of intensity, quality of output and efficiency. Sub-soiling or chisel ploughing requires very robust machines and so power tillers are rarely used for that purpose. For tractors to efficiently work on sub-soils, especially on irrigated fields very stable tractors are required. The stability of EE tractors during such activities is relatively lower compared with MM tractors. Thus for good sub-soiling work using tine cultivators MM tractors are mostly recommended. One main problem encountered by EE machines during sub-soiling is the loss of a firm grip by hinge bars connected to the implements. There is also a tendency for the tines to merely scratch the top soil rather than turn the sub-soil because not enough torque is transmitted to the power take off.

In the case of dry ploughing and wet ploughing, both tractors and power tillers are used. However on very dry soils, EE tractors are likely to lose some fragile parts during traction. Thus though the quality of output in terms of the physical appearance of the soil after dry ploughing by EE and MM tractors may be comparable, the impact on the capital good itself after the farm operation varies. For example, while an MM machine used for dry ploughing in very heavy and dry soils will rarely break any hinges or drawbars in the first 6 to 10 years of use, it is very common to find it happening in EE tractors during the first 18 months of usage.

Thus to successfully use EE tractors for ploughing before the rains, which is a prudent thing to do, requires very experienced operators who correctly set the furrow depth, plough direction and speed so that excessive pressure is not placed on parts which are susceptible to frequent breakage. In other instances some owners adopt a strategy of replacing these susceptible parts with genuine MM spares before they start using their tractors to prevent such breakages. Though the MM machines are better for dry ploughing, except for extremely harsh soil characteristics, the EE ones are also being used, with little or no differences in the quality of work but require more time and patience, and sometimes extra repair cost to get the work done with minimal damage to the capital good. However, if the moisture content of the soil is high enough, say after the first three rains in the season then, the EE tractors can manage the process with less difficulty.

Using the power tiller for dry ploughing can be very cumbersome, especially EE power tillers at the very low end of quality. Thus while some Indian made power tillers can be successfully used for dry ploughing, Chinese ones are rarely successful. The challenge here is also related to the potential damage to delicate parts. The low quality of the materials used in making these EE machines mean that even a very small amount of stress on them leads to break downs. Thus for most users, only the MM power tillers are used for dry ploughing. The MM power tillers produce very good tillage, and at the same time the risk of machine damage is reduced to the barest minimum. In addition, MM power tillers are faster during dry ploughing, saving labour cost in terms of time, and getting more acreage tilled per day. Here even if there have been some rains, EE power tillers are still fragile when used for ploughing.

MM tractors do better when rotavating on irrigated paddy fields than EE ones (Key informant interview with mechanisation officer in the Kongua District, 2012). Thus MM tractors are more popular on such terrains. They are less likely to slip during usage on wet grounds. The design of the wheel system also helps to minimize the likelihood of the machine sinking. Though very high end (quality wise) power tillers like Kubota, Daedong and Kukje (MM) can perform rotavation better than Amec (EE), they are rarely used in such circumstances mainly because they are not easily found on the market. Siam Kubota (MM) can be used to rotavate; however the quality of tillage[25] is not as high as the others, including Amec from China. Because harrowing and levelling exerts relatively

[25] The implement is not propelled by the engine but by the motion of the machine and as such the draft force produced is not high enough to pulverize the soil and debris into a very fine texture.

less stress on capital goods, the use of MM and EE machines for this activity depends on what is available to the farmer and not the requirements of the operation.

6.6 Financing investment and running costs

Procurement of farm machinery and its transportation from the point of purchase to the farmers' home requires capital outlays. Running costs including fuel and oil, as well as operator fees and maintenance of the machinery require money. The sources of capital for the farmer are mainly savings from their farm business and non-farm businesses, loans from family members and sometimes friends. These modes of finance are informal. Some farmers also obtain loans without interest from traders who sell the equipment. Other groups of farmers finance the procurement of their equipment from formal loans obtained from commercial or development banks. These loans may come with intermediaries such as cooperative societies, district assemblies, input support trust funds and special private agricultural support units.

Operational costs were usually handled with revenue accruing from the use of the machine- contract hiring. It should be noted here that for many farmers, benefits accruing from hiring out their machines rarely covers the investment cost. Thus, farmers see contract hiring as a subsidy or a kind gesture to other small farmers, and must be compensated for by government. The inability of farmers to cover the investment cost through hiring out is greater when dealing with very large tractors: at full capacity utilization, most power tiller brands, regardless of their source are profitable, but the same cannot be said of four wheeled tractors. As we shall see in Chapter 8, using the current market prices paid for an acre of tillage work done by a tractor the service does not breakeven. Most owners considering this kind of service provision to other farmers are not likely to breakeven over the entire life of the machine at current real interest rates of 8.05%. For those farmers who do not hire it out at all, but use their tractor or power tiller on their own farm, the capital and running costs for the machine were allocated as part of the farm budget and paid for with revenue from the previous years' earnings.

An interesting observation made during the field visits was a gradual shift of large scale settler farms especially in the tobacco growing areas from owning their own tractors to hiring from other rural entrepreneurs. This may be signalling that the price per acre of tillage in most places where this study was carried out is sub-optimal and clever farmers, even if they did have the capital to invest in machinery will not do so but hire from others who might have not taken the time off to do the necessary computations. It is in the light of these and other issues that the Private Agricultural Sector Support (PASS) initiative which links farmers with markets has evolved in Tanzania to help farmers develop feasible proposals as they attempt to source money for financing farm machinery procurement.

6.6.1 Savings from farm businesses

A substantial proportion of the farmers in our sample (159 out of the 194 machines bought) financed the procurement of their equipment with their own funds accrued usually from the sale of their farm produce for between two to four seasons. This group of farmers financing their investment cost with their own savings were usually those buying power tillers of Chinese origin in the absence of warranty.

Relatively bigger and more successful farmers tend to import their own tractors from Europe, usually second-hand machines which had been used for about three to four years. This practice was common in the Mbeya area where irrigated rice fields were common. There were also a number of farmers especially in the Babati area who went to Zambia and Kenya to buy second tractors being disposed-off by large commercial farms. In such cases transactions are on a 'cash and carry' basis and financed using savings. The savings are sometimes complemented with loans from family members.

Large commercial farms with a long and established history of doing business with the manufacturing companies of tractors, usually receive new models of the machines from the manufacturer to be tried for a period. If they are happy with the model, they go ahead and buy them; using farm profits to cover some of the cost and the manufacturer also gives them additional machines to be paid for over an agreed term, usually with little or no interest.

6.6.2 Savings from non-farm business

The rural economy of Tanzania is rarely anything but agriculture. Formal sector workers such as teachers, health officers or workers at the district assemblies also invest in the rural economy. There are also rural businessmen and women engaged in trading, transportation and housing services who may also double as farmers. Such people sometimes finance the procurement of farm equipment (tractors and power tillers) with income from the non-farm activities they participate in. Households owning farm animals may also sell off a number of their farm animals in order to buy a tractor.

For the formal workers, they are able to either save towards the procurement of the equipment or finance a debt using their status as a government employee to secure a loan. For retiring civil servants or formerly employed private sector workers, some of them use their pension benefits to pay for farm equipment. Others in the informal sector use profits accruing to other businesses they operate to buy tractors and power tillers. In instances as those elaborated here, the farmer may complement what they are able to raise personally with other formal credit lines from commercial and development banks.

6.6.3 Borrowing from family and friends

The nature of farming in the study areas is a household based activity. Thus as young men and women grow up and become of age, their fathers especially, help them to establish their own farms by supporting them to acquire the requisite farm tools, especially in the rice growing areas. Usually such support given to young people by their parents is not a gift; they are to pay back within a period of one to four years. They are not always completely sufficient to buy the farm equipment and so the young person must have also raised some money from his or her own farm to augment what is coming from their parents. Such arrangements are rarely with interest, but come with informally agreed conditions that the machine will be used first to complete family member plots before being hired out to other people.

Friends, who are in most cases also farmers themselves, provide financial support when one decides to buy a machine. This support does not always come in the form of money. It can relate to the transferring of their second hand machines to the prospective buyers and allowing them to pay for it over time. There are instances when there is a down payment required before the buyer takes the machine with payment of the remaining amount settled over a specified time with or without an interest.

6.6.4 Loans without interest from local traders

For small machines, especially those from China without a warranty and sometimes some Indian machines (EE), some local dealers give them to farmers to use for a season and afterwards pay back without any initial down payment. This arrangement is usually based on trust and a long relationship between the farmer and the seller. Some sellers undertake such arrangements if they know that the farmer has unsold farm produce in their barns that they can easily get police (court) order to confiscate if the farmer defaults.

As one trader at Rujewa, the district capital of Mbarali, made me aware:

> "...such arrangements usually do not go bad, the farmers make good of their promise and so the relation and goodwill continue." (Key informant interviews 2012)

It is a very flexible means of financing the investment cost by farmers, and as the seller puts it in the above quote, for very serious farmers, hiring out the power tiller alone in one season alone can cover the acquisition cost. If they are unable to cover it with income from hiring, then they would have to find additional money obtained from their own harvest.

6.6.5 Loans from commercial banks without intermediaries

Commercial banks like Cooperatives Rural and Development Bank (CRDB), National Microfinance Bank (NMB) and National Bank of Commerce (NBC) and others have financial facilities that are available to farmers who want to buy farm machinery. Such credit lines were very popular in the 1980s and 1990s. In those days, cost of such credits ranged from 6% to 20% interest rates (Survey Data, 2012/2013). However since the 2000s such arrangements were curtailed. This curtailment was warranted by commercial banks' effort to mitigate risks associated with direct lending to farmers. Thus members of farmer groups or those identified with the Private Agricultural Sector Support (PASS) initiative stand a better chance of obtaining a bank loan for machinery purchases. Whilst in the past there were facilities for financing second hand machines, current attention by commercial banks is on brand-new ones. With the quality of tractors generally declining on the Tanzanian market (as suggested by distributors and users), it is rare to find a commercial bank which is willing to finance a loan for second hand machinery, though in some cases as suggested by most sellers, some of the second hand machines are of a higher quality than the new ones (Key informant interview with the director of a company which imports second hand tractors from Europe in Morogoro, 2012).

In instances when the commercial bank decides to lend to a farmer directly, then they must do the due diligence themselves to establish that the farmer actually qualifies for the loan. This usually adds to the cost of capital. Therefore most banks are now shying away from this system and shifting the investigation assignment that establishes the credit worthiness of the farmer to cooperative societies, district assemblies, the Agricultural Input Trust Fund (AITF) and Private Agricultural Sector Support (PASS) initiative.

6.6.6 Loans from commercial and development banks with intermediaries

In the 2000s, there was a general recognition that commercial banks were not allocating enough money to the agricultural sector. Prior to that government anticipated such a future happening and so set up the Agricultural Input Trust Fund (AITF) which was hitherto mainly involved in farm inputs like fertilizers and seeds. With a renewed commitment, the AITF redirected some of its funds to finance agricultural inputs. With demands rising, and the AITF unable to meet all such demands, central government decided to start an agricultural development bank to meet farmers' needs.

Again, the funds for capitalizing an agricultural development bank were not easily available. The initial quantum of money raised by central government was given to Tanzania Investment Bank (TIB). TIB is an established development bank and it was tasked to operate this fund off its balance sheet. Characteristically, TIB has urban-based branches. To create farmer access, the bank formed a network with other banks which have more branches across the country. Therefore, TIB lends to other commercial banks at 4% or 5% for onward lending to farmers between 8 and 10% interest rate.

The relationship between commercial banks and farmers is no longer a direct one. The farmer must develop a business plan with the help of the PASS initiative, AITF or their cooperative society. Feasibility studies, land titling and proof of enough assets to be liquidated to cover the loan in case of default are carried out. For farmers wanting to get loans for a power tiller, they must be cultivating at least 10 acres of farm land and for those wanting to buy tractors; they should have at least 40 acres under cultivation. This entry requirement cuts off some poorer households from ever owning machines if their intention is to do so through a credit line. As we shall see in later Chapters, an important characteristic of poor households, as opposed to non-poor households is the quantity and quality of their production asset and this effectively affects their savings and the propensity to accumulate funds for the procurement of capital goods (Sarris *et al* 2006).

Table 6.5 gives an idea of the sources of credit used by MM and EE capital goods owners in financing their investment. Out of the 194 power tillers and tractors under study, 51 of them were obtained through loans. The most important source of credit to

MM users in our sample as a proportion of those using credit is cooperatives (56%). This finding is consistent with the stand point of executives of a cooperative society in Ubaruku, who posited during a focus group discussion that after careful research and consideration, they found that MM power tillers were ideal for their operating conditions and for farmers to be able to pay back their loan, they need power tillers of such quality and durability. Thus, all the 35 machines they have financed since 2006 were of MM origin (Key informant interview with the secretary of Ubaruku SACCOS, 2012). Government sources of credit such as district assemblies and the AITF are also very important for EE owners financing their investment with loans (30.77%). In an interview with an official at the AITF, he mentioned that usually when farmers are asked to get quotations from sellers when they apply for loans, they usually bring in invoices from traders who sell EE machines. They, at the AITF do not put any restrictions on farmers' choice, but probably because the EE machines are cheaper, farmers find it easy to make the 20% down payment required.

Table 6.5: Sources of credit for farmers purchasing their machines with debt

Source of Credit	MM (%)	EE (%)	Combined (%)
Commercial banks[26]	20	23.1	21.6
Cooperatives	56	7.7	31.4
Government[27]	0	30.8	15.7
Friends	8	7.7	7.8
Relatives	8	26.9	17.6
Distributors/dealers	8	3.8	5.9
Total	100	100	100

Source: Field work, 2012/2013

6.7 Conclusion

In relation to the three constituents of technology transfer and diffusion (importation, distribution and usage), various actors play different roles either in a solitary or interactive way with a view to maximizing their utility as government, NGOs, businesses or users (mostly farming households). While the objective of government is to use fiscal and monetary policies to influence the way market systems work, with a view to protect

[26] Commercial Banks here include NMB, TIB, CRDB and NBC

[27] Government sources is defined to include District Councils, Suma-JKT and Agricultural Input Trust Fund

consumer welfare, businesses respond to such government stimuli to maximize marketing margins. The users (who in our case are farmers) are price/product takers in most instances. For example when a farmer in the Turiani area was asked why he chose to buy the kind of tractor he is using, he responded by saying that:

> "...this is what the government agents had on sale, and the financial institution which provided the loan was prepared to finance a transaction supported by government: actually I had no choice...giving the choice I would have gone for something else..." (Survey response from a farmer in the Turiani area, 2012)

Having established the value chain that is responsible for the transfer, diffusion and penetration of MM and EE mechanisation technologies and the role various actors play and the mechanisms these actors employ to accomplish their roles, we now turn our attention to the distinctive nature of characteristics embodied in the technologies in the next chapter. An attempt is made to delineate the engineering and economic distinctiveness of the alternative techniques and how these differences make them suitable or otherwise for different users. We also discuss the productivity ratios (of investment/capital, labour and output) and economic rates of return or profitability of investment associated with different categories of tillage techniques, mainly defined by the origin of the soft technology and where the hardware is produced.

Chapter 7 : The Distinctive Nature of Capital Goods

7.1 Introduction

This Chapter assumes that the origin of the power tiller or tractor technology influences its engineering, physical features and engineering performance. Manufacturer differentiation affects the physical, inherent efficiency and costs associated with any power tiller or tractor from a particular country of origin. The characteristics of a power tiller or tractor reflects the social, economic, institutional standards and industrial governance of the source of innovation (Ruttan, 2001). Manufacturers consider the characteristics of local demand: focusing on the purchasing power of users and standards regulatory regimes impose. The endowments, capabilities and knowledge base of the industrial sector of the country of origin are also crucial. It determines the character of technologies that are developed. Invariably what is sold to the farmer in Tanzania reflects the cultural, social, and economic as well as factor endowments of the country of origin and the characteristics or business objectives of importers and distributors within the value chain.

For a critical examination of the distinctiveness of the various strands of techniques, we make a comparison of their engineering and quality features, building on details outlined in Chapters 5 and 6. This then naturally leads us into a discussion of the coefficients of production. The physical productivity ratios are determined by the output generated in relation to the labour and capital consumed per season[28] and where relevant on a per acre basis. To get an understanding of how well a particular category of technology is doing or otherwise, technical efficiency measures are compared across power tiller or tractor groupings (Stewart, 1977).

Beyond the technical characteristics of the capital goods is their profitability for users. To assess the Net Present Values (NPV), costs and benefits streams associated with each

[28] In our case the season consists of all farm and non-farm activities carried out with the capital good by the farmer 12 months before the day of interview.

category of technology is calculated. They are thus compared using the real interest rate for Tanzania (8.05%). The associated benefit-cost ratios (BCR) are also computed. These computations are made with the five operational conditions outlined in Chapter 6 in mind: first, power tillers on paddy fields (small scale farms); second, tractors on maize fields (small, medium, large); third, tractors on maize and tobacco fields (medium and large scale); fourth, tractors on upland rice and sugar cane fields (small, medium and large scale) and; fifth, tractors on irrigated rice and sugar cane fields (small, medium and large scale). In addition, one sensitivity analysis is estimated. This sensitivity scenario assumes that current government subsidies on all the machine categories under the five operating conditions are removed, and a similar computation for NPV and BCR is undertaken. All computations in this chapter and those that follow are presented in Tanzanian Shillings (TSH). At the time of the data collection in 2012, £1.00 was equivalent to TSH2380.00. In addition each computation is presented reflects both the actual and rated capacity utilization of each capital good under consideration. The actual computations are based on the observed utilization levels during the season under consideration whilst the rated scores are based on the maximum potential utilization levels of the machine.

The discussions in this chapter are in two tiers. First, engineering and quality distinctiveness, which essentially reflects factory level differences, are discussed. They are presented using the aggregate means of MM_0, MM_1, EE_1 and EE_0 categories in the sample. Performance computations (productivity ratios, gross margins and benefit-cost analyses) are presented using specific examples of brands of MM_0, MM_1, EE_1 and EE_0. The objective for this analysis is to assess farmer benefits when they choose an MM or EE machine. The second objective is to establish the economic outcomes of alternative choices under particular farming systems. We begin in section 7.2 by giving a general overview of the field survey. Some characteristics of the participating farmers are discussed, laying out the background of their regions, crops, soils and farm sizes and other features pertaining to access. We shall expand this discussion on farm household characteristics in the next chapter when the effects of choice on poor and non-poor users are discussed.

7.2 The field survey

As we saw in Chapter 4, 194 capital goods were surveyed. These 194 machines belonged to 192 farmers. Of these, 115 had EE origins, with the remainder coming from MM sources. By scale, there were 95 and 99 power tiller and tractor units respectively in the sample. As shown in Table 7.1, there were 36 MM power tillers and 59 EE ones. A similar sub sample was drawn for tractors, with MM and EE machines comprising 43 and 56 respectively. In total, 192 machine owners and caretakers were interviewed across five regions. Two respondents had more than 1 machine in the study. A majority of the power tillers studied were located in the Mbeya region (57) and a greater number of the tractors were located in the Dodoma region (43). The remaining power tillers and tractors spread across the other three regions. Officials and workers in a large scale sugar plantation with over 50[29] tractors in use were also interviewed in the Morogoro Region.

The four main crops grown by respondents were maize, rice, sugarcane and tobacco. A few of them cultivated pulses and vegetables. In order of importance, each farmer was asked to list three crops he/she cultivated in the previous season. For power tiller owners, the main crop they cultivated was rice. Only a handful cultivated maize, regardless of the source of the machine. In the case of tractors, we find that users of MM capital goods mostly cultivated rice as their most important crop, followed by maize. On the contrary, most EE tractor users, cultivated maize as the most important crop, followed by vegetables and pulses. In the case of sugarcane and tobacco cultivation as main crops, more MM users participated than their EE counterparts. Thus generally, MM machines especially at the large scale level concentrate more on cash crops while the

[29] These 50 tractors are however not included in the survey

EE ones concentrates on food crops- an observation which may have pro-poor implications (See Chapter 9).

Table 7.1: Users, crops, soils, scale and origin of machines covered

Variable		MM		EE		Total
		MM_0	MM_1	EE_1	EE_0	
Scale	Power Tillers	4	32	3	56	95
	Tractors	33	10	28	28	99
Location	Power tillers					
	Dodoma	_	_	_	1	1
	Iringa	1	2	_	16	19
	Manyera	1	8	_	6	15
	Mbeya	2	22	1	32	57
	Morogoro	_	_	2	1	3
	Tractors					
	Dodoma	3	2	12	26	43
	Iringa	4	_	12	_	16
	Manyara	11	1	2	1	15
	Mbeya	7	_	_	_	7
	Morogoro	8	7	2	1	18
Primary crops	Power tillers					
	Maize	_	_	_	3	3
	Rice	4	32	3	51	90
	Tobacco	_	_	_	_	_
	Sugar cane	_	_	_	_	_
	Pulses	_	_	_	2	2
	Tractors					
	Maize	14	2	15	23	54
	Rice	15	4	3	3	25
	Tobacco	1	2	2	0	5
	Sugar cane	2	2	1	1	6
	Pulses	1	_	7	1	9
Soils	Power tillers					
	Sandy	1	_	_	3	7
	Loamy	_	_	_	2	5
	Clayey	2	32	3	49	85
	Tractors					
	Sandy	14	2	15	23	60
	Loamy	2	2	9	1	5
	Clayey	17	6	4	4	32
Sample total		79		115		194

MM- Matured Markets; MM_0- MM technologies made in MM; MM_1- MM technologies made in EE
EE- Emerging Markets; EE_1-MM technologies adapted to EE; EE_0- EE technologies made in EE

Source: Field Survey, 2012/2013

Considering the soils on which the machines are used, the study finds that most power tillers, whether from MM or EE, were used on clay textured fields. A few of them were used on sandy soils. By origin, tractors on the other hand had some differences in terms of the soil texture on which they were used. While more MM tractors were found on clay regimes, the EE tractors concentrated around loamy and sandy soils. See Table 7.1.

7.3 Basic engineering distinctions of capital goods

From field interviews in 2012, we find that on average, the age of the capital goods within our sample were 3.4 years and 7.0 years for power tillers (n=95) and tractors (n=99) respectively (Table 7.2). Within the origin sub-groups, the ages of power tillers and tractors were significantly different at the 1% level. MM_0 power tillers were the oldest (3.5 years), with EE_1 machines being the least (2.3) in terms of age. For tractors, MM_0 were the oldest with an average age close to 14 years and the least were MM_1, at 2.5 years old; EE_1 and EE_0 tractors were aged between these two extremes, though much closer to the minimum than the maximum.

These findings suggest that while MM and EE power tillers had comparable vintages, tractors did not. That is to say, recent acquisitions of tractors by farmers were mainly from EE sources. Thus whilst about a decade ago, more farmers within the sample bought an MM machine, current trends show that procurement of EE tractors in the past three or four years is on the ascendency. Aside from these vintage differences, there were also engineering distinctiveness. We discuss these differences in the following sub-sections for MM and EE capital goods in turn and summarize some of the indicators in Table 7.2. The information in these sub-sections is based on detailed information received from field research in Tanzania in 2012/2013. Some sections are supported with a review of relevant literature.

7.3.1 MM (MM_0 and MM_1) power tillers

MM_0 power tillers had the lowest horsepower among the four categories (13.5Hp on average). Their power-take-off shaft is located on the side of the machine and not at the rear. Implements attached to MM_0 power tillers were propelled by drawbar horsepower harnessed from the engine and not the pull of the machine. MM_0 power tillers are believed by users to be assembled by robots and so the parts are well fitted together. In addition, they are fabricated with metals of high carbon steel. In the estimation of users and experts, these machines can be used for over 10 to 12 years, given adequate servicing and maintenance. On the other hand, the average horsepower of an MM_1 power tiller was a little over 14Hp. For most of them in use today, they do not deliver their power through the draw bar, but through the motion of the machine. However, there has been a recent introduction of models which deliver their power through the drawbar. Estimates by users suggest that MM_1 machines can be used for over 6 years without major engine problems. For both groups of power tillers (i.e. MM_0 and MM_1) the gears within the engine and gear box are smaller in size and also hardened to produce a higher power per unit of fuel combusted. They have faster speed, both on the road and on farms when compared with EE power tillers. MM_0 power tillers are however more stable on the field than MM_1, though they have comparable weights.

7.3.2 EE (EE_1 and EE_0) power tillers

The EE_1 power tillers are also of the 14Hp range, on average, but slightly heavier in weight than the MM models, though not as stable. Implements attached to them draw power from the engine through the drawbar. They have an average economic life of close to 4 years. The materials used in their fabrication and the robustness in terms of how well the parts fit together are lower than the MM_1 sub-group.

EE_0 power tillers are by far the heaviest in weight and highest in horsepower (about 16Hp) on average. They however possess the lowest expected economic life of about 3 years, and this age attained only if used with a lot of care and consideration. According to users, EE_0 power tillers bought during the early 2000s had a longer lifespan than those being imported today, though prices in real terms have not declined significantly. They also draw power for the implements from the engine through a drawbar at the rear. The fitting of parts especially within the engine and gear box is generally not well executed. The carbon content of the metals used for casting parts is lower when compared with other brands. These engineering defects generally cause a lot of leakages of engine oil and grease during usage. In general, EE power tillers have a lower speed on rural roads and on the farm as well. During usage, it makes a lot of noise, produces intense smoke and generates a lot of heat. Some parts get ripped off easily and can cause injury to users. It vibrates a lot, and creates discomfort for the user.

7.3.3 MM (MM_0 and MM_1) Tractors

MM_0 tractors mostly had a horsepower averaging 70. They are usually FWA, but some of them in the low horsepower ranges are 2WD (especially the very old ones). MM_0 machines which are 80Hp and above are 4WD. The engine systems are typically four cylinder engines and have an economic life of between 12 and 15 years with the need for engine refurbishment at the end of every 6 to 8 years. They are relatively heavier than the other sub groups and more stable when used on farms. Older vintages are very robust and made up of extremely strong metals and operate with manual steering. Newer vintages use power steering and more sophisticated electrical systems that can allow for programming of the tractors with computers. These electrical additions sometimes pose a challenge for mechanics during repairs.

MM_1 tractors are lighter in weight and less stable than their MM_0 counterparts on average. Those in our sample had an average horsepower higher than the MM_0 ones; about 77Hp on average. Typically, users of MM_1 tractors estimated that they have an economic life of about 8 years on average. They are mostly FWA or 4WD, and the engine system is composed of at least 4 cylinders. Metals used in their fabrication are not as robust as those of the MM_0.

7.3.4 EE_1 and EE_0 Tractors

EE_1 tractors had a horsepower of 62 on average and an expected economic life of a little over 4 years. They mostly have four-cylinder engines, but a few of them have three cylinder engines. They are mostly 2WD, but occasionally may have a FWA wheel system. The teeth of the gears within the engine and gearbox are usually brittle and often break during usage. They are quite stable, but some of the parts are relatively fragile and are usually damaged on rough terrains. EE_0 tractors dominating our sample are somewhat different from the other groups in terms of the engine make-up. They are usually three-cylinder engines constructed using the *hammer mill*[30] principle. In this case each of the cylinders can be serviced separately without the need to dismantle the whole engine. Almost all of them are 2WD with a horsepower range averaging 48. They are lighter in weight, with less stability compared with all the others and generally include power steering. Gear boxes of most of these tractors were often too small to match the engine of the tractor. Both EE_1 and EE_0 tractors produces a lot of noise during usage (Table 7.2).

Table 7.2: Average age, economic life and horsepower by scale and category

Scale	Variable	MM_0	MM_1	EE_1	EE_0	Mean
Power tiller	Age (years)	3.50	3.53	2.33	3.39	3.41
	Economic life (years)	10.25	6.22	3.66	3.33	4.69
	Horsepower	13.50	14.13	14.00	15.92	15.16
Tractor	Age (years)	13.97	2.50	3.46	3.81	7.00
	Economic life (years)	12.70	5.25	6.61	4.21	7.44
	Horsepower	69.21	77.00	57.68	62.39	48.62

Source: Field Survey, 2012/2013

7.4 Machine performance: land preparation, transportation and other uses

As we saw in Chapter 6, field operations adopted on farms in this study followed the chain of activities listed in Table 7.3. Generally, for farm lands with heavy sub-soils, tine cultivation (sub-soiling) is done first. On well drained sub-soils, ploughing is carried out first (for all crops), followed by paddling (in the case of swamp rice and sometimes sugarcane) or harrowing (for maize and tobacco fields). Paddling and harrowing are sometimes followed by levelling, and for crops grown on moulded soils, ridges or mounds are constructed using tractor or power tiller drawn implements when construction is not manually done.

[30] This type of engine, according to repairers in the study is very easy to service and maintain

With the land ready for planting, tractors and power tillers can be fitted with implements that can sow seeds in rows (with precision) or broadcast seeds. For crops like rice, especially when seedlings are used or sugarcane where the planting materials are usually cuttings, they are either sown manually or with specialized planting machines. These machines are not attached onto tractors or power tillers. Tractors and power tillers fitted with pump-sets are also used to pump water from dams to irrigate crops. During the growing period of crops, tractor or power tiller drawn implements can be used to apply fertilizers, weedicides and pesticides. Mechanical weeding within rows of crops can also be done using implements hitched on to the tractor or power tiller.

Table 7.3: Farm operations that tractors and power tillers can perform

			Sampled farmers (Count)	
Operation	**Stage of operation**	**Activities**	**Tractors**	**Power tillers**
On-farm	Primary farm (Land preparation)	Sub-soiling	5	0
		Dry ploughing	98	60
		Wet ploughing	80	65
		Rotavation/Paddling	45	80
		Harrowing	45	5
		Levelling	25	30
	Secondary farm	Precision sowing	0	0
		Irrigation	0	10
		Agrochemicals app	5	0
		Weeding	10	0
		Harvesting	12	0
Off-farm	Post-harvest	De-husking	0	0
		Shelling	10	0
		Grinding	1	0
	Others	Transportation	85	60
		Power generation	0	3

Source: Field Survey, 2012/2013

During harvesting, a tractor drawn trailer, moving in tandem with a combine harvester serves as a bucket for the harvested crop. De-husking, shelling, grinding and winnowing of grains can also be done with post-harvest implements hooked onto stationary tractors or power tillers. Transportation of inputs onto the farm, and farm produce from the farm to the farm house or the market centre is also carried out by these technologies. For rural communities without access to electricity supply from the national grid, power tillers are sometimes used to generate energy to power lights and other home appliances.

For the analyses of machine performance (which compares MM and EE tractors and power tillers), the study concentrates on land preparation and transportation. The output in terms of land preparation is captured using area cultivated. For transportation, total earnings the farmer made from all transportation services sold in the season under consideration are used. The time dimension of the analyses covers the activities for which farmers used their capital goods in the year prior to my field visit (that is the past 12 months before the interview).

7.5 Output and coefficients of production

Power tiller operators in the sample spend an 8-hour day in the field on average either ploughing or paddling. Sometimes, work goes on into the night to compensate for time lost as a result of machine breakdowns during the day. Assignments needing urgent completion are continued at night. The predominant operating conditions (hereafter, OC) under which power tillers work is small scale paddy fields, which for the purposes of the tables in this Chapter are designated as OC1 (Refer to Section 5.6 of Chapter 5). Under OC1, we compare four power tillers: Kubota (MM_0) from Japan, Siam Kubota (MM_1) from Thailand, Greaves (EE_1) from India and Amec (EE_0) from China.

A typical day for a tractor operator is 8 to 12 hours but some of this time goes into driving the tractor from home to the field and loading the tractor with fuel and lubricants. When tractors are faulty, downtime during usage may also take a significant amount of the period. The operators may spend some time working at night, when they have contracts far away from home. In other instances when there is an urgent need to complete an assignment so as to move to another town or area the next day, night work may be carried out. It will be difficult, and in some respect misleading to compare the performance of tractors without recognising the fact that generally, MM tractors in our sample work on relatively heavier textured soils compared with the EE ones, even under similar farming systems. Thus average computations here are made in relation to the area in which these tractors worked most of the time during the year. Thus as discussed in Chapter 5, there are four typical OCs under which tractors work, which in our tabulations are represented by OC2, OC3, OC4 and OC5. Under OC2, we have maize being cultivated on largely sandy soils with legumes and pulses as intercrops. OC2 is typical in the Dodoma area and we discuss two tractor models as alternatives: Farmtrac 45 and Swaraj (Medium sized tractors with horsepower between 40 and 49).

OC3 is predominantly sandy-loam to loam and they typically cultivate maize and tobacco with vegetables as intercrops. In cases where the rains are bimodal, the maize crop is cultivated twice in a year. Under this condition we compare Finish Valtra (MM_0), Brazilian Massey Ferguson (MM_1) and Pakistani MF (EE_1) - all in the medium sized tractor range with horsepower between 50 and 65. For an EE_0 alternative for OC3 we could have had Mahindra tractors. However, they are very new on the Tanzanian market and so respondents did not have enough experience to tell us about performance indicators for computation of distinctiveness. OC3 are found mainly in Iringa and Babati regions.

OC4 consists of upland rice or sugar cane on heavy textured but relatively drier clays, found mainly in Mbeya, Morogoro and Babati. The machines to be compared under OC4 are New Holland-Italy (MM_0), Massey Ferguson-Brazil (MM_1) and Farmtrac 70-India (EE_1). Finally, New Holland-Italy (MM_0), New Holland- Turkey (MM_1), New Holland- India (EE_1) and YTO -China (EE_0) are compared under OC5 where conditions are like OC4 except for the presence of artificial irrigation. Tractors under OC4 and OC5 mostly have horsepower between 65 and 85 or sometimes even higher.

It must be emphasized that the tractor brands compared here are not the exhaustive list from which farmers can choose. The list of brands and models of tractors being compared here has been carefully selected by the author to reflect machines which were known to, and used by, farmers for at least one year prior to the interviews. There are some models which are not in themselves represented in the computations we make here, but other models which find space in our tables serves as a proxy for them. For instance, Farmtrac computations could easily be used as a proxy for Powertrac and Escorts, since they all come from the same manufacturer and we can assume, are of the similar engineering configuration with only slight differences. Similarly, Massey Ferguson from Pakistan and TAFE from India can be substituted for one another provided their horsepower ranges are similar.

In Table 7.4 and 7.5, we compare the performance of power tillers, using acreage cultivated per man hour for each OC. Generally for power tillers in our sample, being used under OC1, MM_1 machines achieve the maximum average of acreage ploughed per day (3.22) whilst EE_1 machines paddle the largest area (2.91) per day. At the bottom, in terms of acres ploughed and paddled per day we find EE_0 and MM_0 power tillers respectively. However, in terms of the quality of ploughing, farmers generally prefer MM_0 followed by MM_1. MM_0 again produces the best quality of paddling in the opinion of farmers. This is followed closely by EE_0. Labour requirements for a day's full employment of power tillers is highest for EE_0 (2 men per day) mainly because of the weight of the machine and the vibration levels experienced by the operator during usage which exerts more pressure on the muscles of the operator compared with other categories of power tillers. The number of operators used per day does not always effectively influence the number of hours spent working per day since the operators sometimes work in turn, though in most cases they both mind the machine throughout the usage period.

As one moves from MM to EE tractors, for all OC2 to OC5, there is a general decline of acres tilled per day by the various brands under consideration, regardless of the operating conditions. Variation in employment per day in terms of total men hired depends more on the operating conditions rather than the specific brand. Consequently as one moves from OC2 (sandy conditions) to OC5 (heavy clay), we see a rise in the number of people employed per day. This in turn affects the man hours per day. On the whole, we find that EE tractors are more labour intensive than MM ones.

Table 7.4: Tillage performance of technologies: output and labour inputs (ploughing)

	Variable	*MM_0*	*MM_1*	*EE_1*	*EE_0*
Power tillers					
		Kubota	*Siam Kubota*	*Greeves*	*Amec*
	Output per day in acres (O)	2.84	3.22	2.46	2.2
	Average employment (count)	1.00	1.00	1.50	2.00
	Man hours per day (L)	8.00	8.00	12.00	16.00
OC1	Acres per man hour (O/L)	0.36	0.40	0.21	0.14
	Man hours per acre (L/O)	2.82	2.48	4.88	7.28
	Hours spent per acre (H)	2.82	2.48	3.25	3.64
Tractors					
	Specific brands			Farmtrac 45	Swaraj
OC2	Output per day in acres (O)			13.76	8.54
	Average employment (count)			1.50	1.00
	Man hours per day (L)			12.00	8.00
	Acres per man hour (O/L)			1.15	1.07
	Man hours per acre (L/O)			0.87	0.94
	Specific brands	Valtra (Finland)	Massey Ferguson (Brazil)	Massey Ferguson (Pakistan)	
	Output per day in acres (O)	15.00	15.00	14.40	
OC3	Average employment (count)	1.50	1.50	1.50	
	Man hours per day (L)	12.00	12.00	12.00	
	Acres per man hour (O/L)	1.25	1.25	1.20	
	Man hours per acre (L/O)	0.80	0.80	0.83	
		New Holland (EU)	MF (Brazil)	Farmtrac70 (India)	
	Output per day in acres (O)	10.78	8.00	7.00	
	Average employment (count)	2.00	2.00	2.00	
OC4	Man hours per day (L)	16.00	16.00	16.00	
	Acres per man hour (O/L)	0.67	0.50	0.44	
	Man hours per acre (L/O)	1.48	2.00	2.29	
		New Holland (EU)	New Holland (Turkey)	New Holland (India)	YTO (China)
	Output per day in acres (O)	8.00	7.50	6.00	6.00
OC5	Average employment (count)	2.00	2.00	2.00	2.00
	Man hours per day (L)	16.00	16.00	16.00	16.00
	Acres per man hour (O/L)	0.50	0.47	0.38	0.38
	Man hours per acre (L/O)	2.00	2.13	2.67	2.67

MM- Matured Markets; MM_0- MM technologies made in MM; MM_1- MM technologies made in EE
EE- Emerging Markets EE_1-MM technologies adapted to EE; EE_1- EE technologies made in EE

Source: Field Survey, 2012/2013

Table 7.5: Tillage performance of technologies: output and labour inputs (paddling and harrowing)

Variable		MM$_0$	MM$_1$	EE$_1$	EE$_0$
Power tillers (paddling)					
OC1		Kubota	Siam Kubota	Greeves	Amec
	Acres per day (O)	2.67	2.78	2.91	2.72
	Employment (count)	1.00	1.00	1.50	2.00
	Man hours per day (L)	8.00	8.00	12.00	16.00
	Acres per man hour (O/L)	0.33	0.35	0.24	0.17
	Man hours per acre (L/O)	2.99	2.88	4.12	5.88
Tractors (Harrowing)					
OC2	Specific brands			Farmtrac 45	Swaraj
	Output per day (O)			14.00	12.00
	Employment (count)			1.50	1.00
	Man hours per day (L)			12.00	8.00
	Acres per man hour (O/L)			1.33	1.50
	Man hours per acre (L/O)			0.75	0.67
OC3	Specific brands	Valtra (Finland)	MF (Brazil)	MF (Pakistan)	
	Output per day (O)	18.00	18.00	16.00	
	Employment (count)	1.50	1.50	1.50	
	Man hours per day (L)	12.00	12.00	12.00	
	Acres per man hour (O/L)	1.50	1.50	1.33	
	Man hours per acre (L/O)	0.67	0.67	0.75	
OC4	Specific brands	New Holland (Italy)	MF (Brazil)	Farmtrac 70 (India)	
	Output per day (O)	15.00	15.00	12.00	
	Employment (count)	2.00	2.00	2.00	
	Man hours per day (L)	16.00	16.00	16.00	
	Acres per man hour (O/L)	0.94	0.94	0.75	
	Man hours per acre (L/O)	1.07	1.07	1.33	
Tractors (Paddling)					
OC5	Specific brands	New Holland (EU)	New Holland (Turkey)	New Holland (India)	YTO (China)
	Output per day (O)	14.00	13.00	12.00	12.00
	Employment (count)	2.00	2.00	2.00	2.00
	Man hours per day (L)	16.00	16.00	16.00	16.00
	Acres per man hour (O/L)	0.88	0.81	0.75	0.75
	Man hours per acre (L/O)	1.14	1.23	1.33	1.33

MM- Matured Markets; MM$_0$- MM technologies made in MM; MM$_1$- MM technologies made in EE
EE- Emerging Markets EE$_1$-MM technologies adapted to EE; EE$_1$- EE technologies made in EE

Source: Field Survey, 2012/2013

7.5.1 Revenue and costs

We now turn our attention to a discussion that examines the revenues and cost structure of the different types of capital goods under the five OCs. The computations are done in terms of actual and rated area cultivated (ploughing, paddling and harrowing) during the season under consideration. The difference between the actual and rated work done per season gives ample indication of capacity utilization of the various categories of machines. In addition, a computation of the benefits[31] realised from services rendered with the machine is done. These services include transportation, water pumping, shelling, grinding and power generation.

A model for the prediction of suitable field work days for agricultural tractors under Tanzanian conditions was developed using historical weather data. The model suggests that in the case of tillage operations, the work days vary between 19 and 50 days (Simalenga T. E., 1989). In computing the rated revenue for each brand under the various OCs, an average of the range of work days predicted (34.5 days) is used. In computing the rated revenue, the study relies on simple proportions. The simple proportion formulation assumes that the relationship between the area cultivated, cost incurred in cultivating that area and the benefits realized have a linear relationship. This may not be the case. But the current study does not have enough data to establish and use an appropriate functional form for the three variables. In the next sub-section we begin with an estimation of gross revenue.

[31] Benefits that this study fails to capture include those from transportation activities on a farmers' own farm. While we tried to do so, it was very difficult for the farmers to recollect for instance transportation of their own products using their machines and how much it would have cost if it was to be paid for. A weak proxy for going around this measurement problem was to multiply their farm output (bags of rice, maize, sugarcane or tobacco) by the average cost of transporting each bag from the farm to the farm house assuming that all of them were indeed transported using power tillers or tractors. This strategy and assumption will however introduce data noise which we cannot assume to be randomly distributed. We therefore limit our comparison to revenue from tillage activities (on own farm and contract hire services) and other activities, mainly transportation of goods for others at a fee.

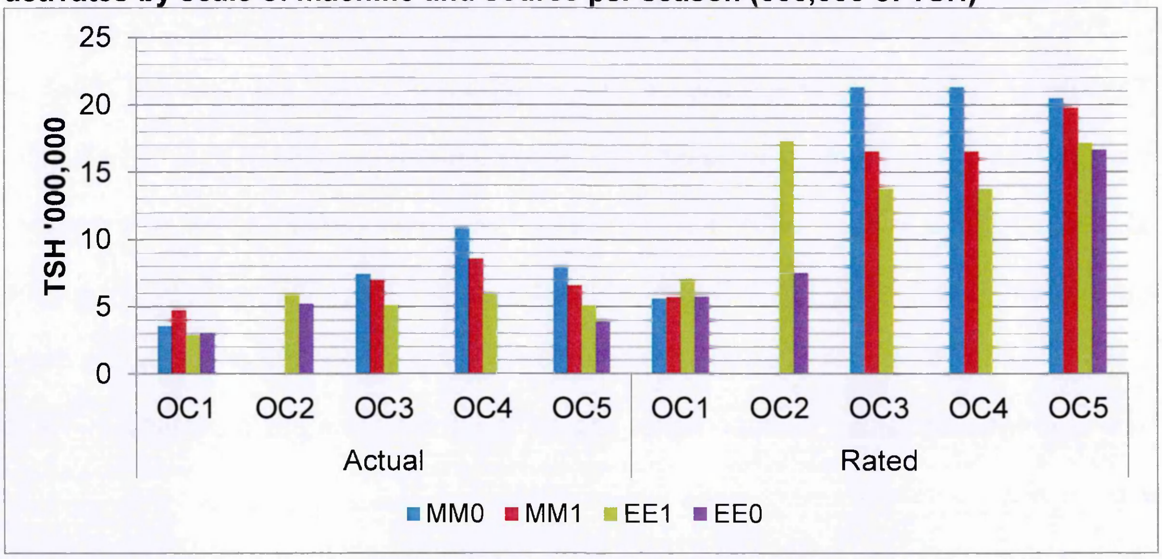
7.5.2 Gross revenue

On a per acre basis, whether ploughing or paddling, power tillers charge higher than a tractor on contract hire because of the labour and time intensities. However, power tillers on average charge higher prices for paddling than for ploughing. There are however slight differences amongst the different categories of capital goods by origin. In the case of hiring tractors, charges for ploughing and paddling are generally more expensive than harrowing. In 2012 power tillers on contract high generated TSH55000 to TSH58000 per acre whilst a tractor generates between TSH35000 to TSH36000 per acre on average to the owner. These figures largely depend on the type of machine, the soils on which they are working and the community. There are also significant differences in terms of the amount charged for use of the different categories of tractors and relative to the community in which they work.

There is ample evidence from the data to suggest that because power tillers generally operate under similar soil conditions (clayey), the prices they charge are not particularly affected by soil texture. The price charged is rather influenced by the degree of competition between the machines in the community. That is, when supply is high, prices fall and vice versa. However for tractors, as one moves from EE machines which are mostly used on sandy soils to MM ones which are predominately found on clayey soils, there is a gradual increase in the average charges, for ploughing especially. Based on the per acre charge, reported cultivated area and benefits from other activities, revenue realized per season for each of the four categories of machines, by scale, is estimated for each OC. Figure 7.1 gives a summary.

Computations for both power tillers and tractors show that revenues obtained by MM machines are consistently higher than the EE ones. This is an effect of both the average price charged per acre and the total work done (acres tilled) during the season. These revenue computations, in and of themselves are not enough grounds for justifying economic profitability. We shall therefore proceed in the next three sub-sections to discuss profitability in a more elaborate way. Attention is paid to the cost components associated with these revenues. The impact of the lifespan of machines and the impact of the degree and frequency of maintenance and repair have on the profitability is also examined.

Figure 7.1: Gross revenue from land preparation, transportation and other activates by scale of machine and source per season (000,000 of TSH)



Source: Author's computation, 2013

7.5.3 Cost structure: investment and running costs

a. Fixed costs (acquisition costs: historical and replacement)

Any measure of capital assumed here will raise a number of theoretical questions regarding their comparability and homogeneity since the machines were bought at different times in different markets (Stewart, 1977). Some of the machines are still sold new, whilst others are no longer on the market. The number and value of implements attached to each power tiller or tractor at the point of purchase was also different. In addition some of the machines were purchased brand-new while others were second-hand. Users, who bought their capital goods on credit, may have different loan arrangements. Consequently, this affects the interest to be paid (percentage and spread) and the effective cost of the machine.

The average ages of power tillers in the sample are comparable for both MM and EE machines. That is their vintage are not significantly different. A bigger problem arises when considering tractors. The average ages of MM and EE tractors are significantly different. To deal with some of these challenges, in the first instance, the owners of the tillage equipment supplied the acquisition costs. Second, information on current prices was collected from distributors and regulatory authorities to serve as replacement costs.

To further adjust for differences at the purchasing point; the average cost of transportation to the home of the user is also computed. In the case of this study, almost all the machines in use still had a current market. Even though a few of them had experienced some engineering modifications and could affect their current prices, the study assumes that such changes are small and do not affect real prices significantly. The average acquisition, transportation and replacement costs are presented in Table 7.6.

It is important to note here that the relatively low average cost of MM_0 tractors should not come as a surprise. Some of these machines were either obtained as second-hand or even third-hand several years ago. Thus, even for those obtained as new machines, their prices would have depreciated a great deal. The current prices however suggest that MM machines have a consistently higher acquisition cost than the EE machines.

In terms of access, MM users generally travelled longer distances to buy their machine compared with EE users. Power tiller users who had MM machines on average journeyed about 329 km to buy their capital goods, while EE power tiller users travelled 273km. The difference in the distance was however not statistically significant at the 10% level. Users of MM and EE tractors within the sample bought their equipment by travelling an average of 252km and 171km respectively and the difference was significant at 10%. Thus on the whole, users of EE machines have easier access in terms of where sellers are located than their counterparts who use MM machines.

Table 7.6: Average acquisition cost[32] of machines, by category and scale. (TSH 000,000)

Technology/OC	MM_0	MM_1	EE_1	EE_0
Power tillers				
OC 1	Kubota	*Siam Kubota*	*Greeves*	*Amec*
Total acquisition cost	8.73	7.73	7.44	3.65
Acquisition cost	8.71	7.68	7.36	3.57
Transportation cost	0.02	0.05	0.08	0.08
Replacement cost	16.00	13.00	8.00	6.00
Tractors				
OC 2			Farmtrac 45	Swaraj
Total acquisition cost			15.43	22.47
Acquisition cost			15.33	22.43
Transportation cost			0.10	0.04
Replacement cost			18.00	24.00
OC 3	Valtra (Finland)	MF (Brazil)	MF (Pakistan)	
Total acquisition cost	60.6	60.77	26.20	
Acquisition cost	60.00	60.00	26.00	
Transportation cost	0.60	0.77	0.20	
Replacement cost	65.00	68.00	26.00	
OC 4	New Holland (EU)	MF (Brazil)	Farmtrac 70	
Total acquisition cost	65.6	60.77	24.93	
Acquisition cost	65.00	60.00	24.83	
Transportation cost	0.60	0.77	0.10	
Replacement cost	70	68.00	25.00	
OC5	New Holland (Italy)	New Holland (Turkey)	New Holland (India)	YTO (China)
Total acquisition cost	65.60	50.60	44.63	22.60
Acquisition cost	65.00	50.00	44.00	22.00
Transportation cost	0.60	0.60	0.63	0.60
Replacement cost	70.00	55.00	46.00	24.00

MM- Matured Markets; MM_0- MM technologies made in MM; MM_1- MM technologies made in EE

EE- Emerging Markets EE_1-MM technologies adapted to EE; EE_0- EE technologies made in EE

Source: Field Survey, 2012/2013

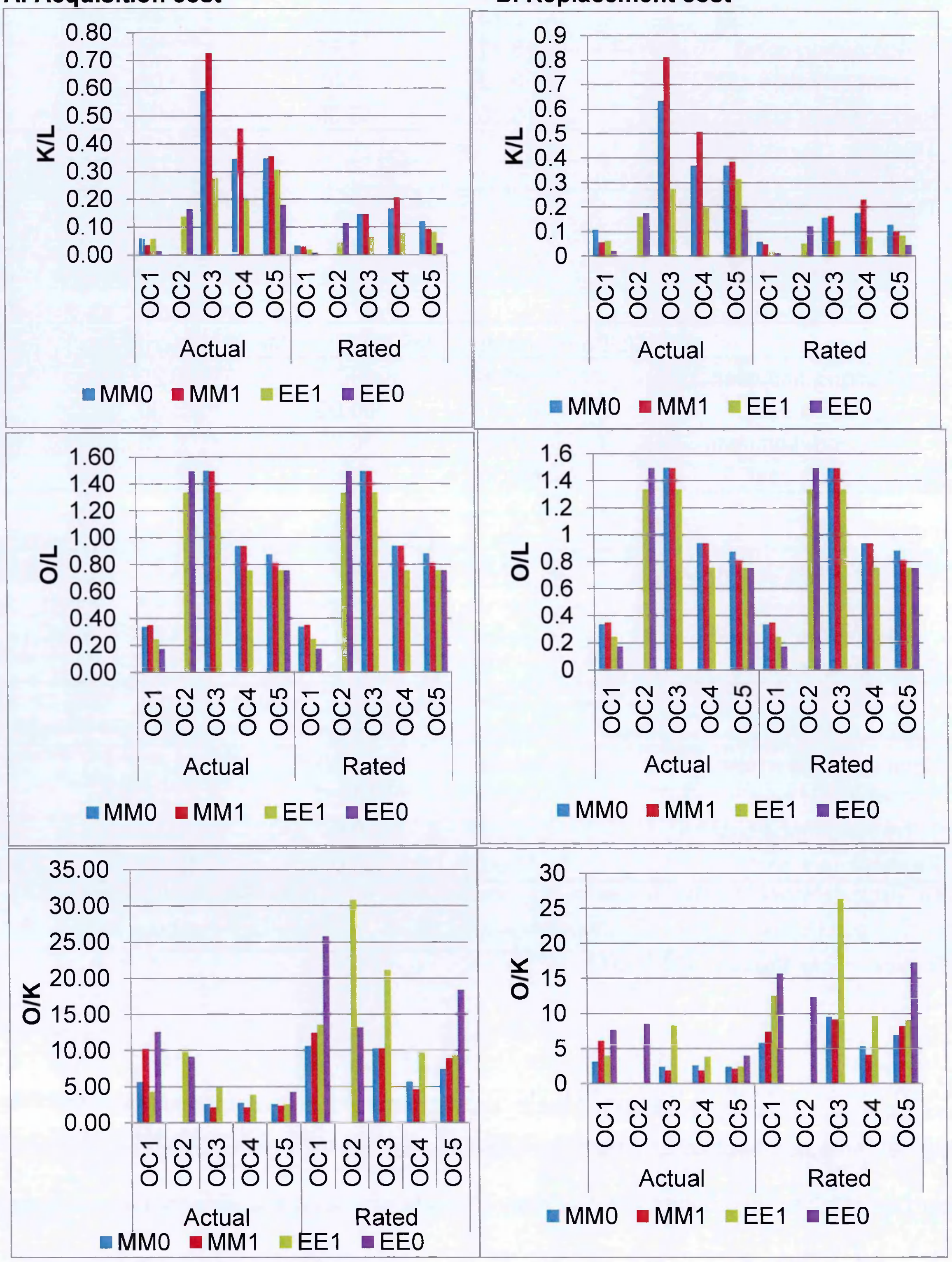
Using the current prices, we find that the ratios generally rise for all machine categories; both at the power tiller and tractor scale under the various OCs. Investment requirements per unit of labour and output are also higher for MM machines than it is for EE machines

[32] This is the same as the historical costs supplied by the farmers

regardless of the scale. On the other hand, EE machines are more labour intensive than their MM counterparts.

Figure 7.2: Efficiency ratios using acquisition and replacement costs

A. Acquisition cost **B. Replacement cost**



Source: Field work, 2012/2013

Figure 7.2, demonstrates the investment per man hours and investment productivity in one season of power tiller and tractor usage. Generally, from power tillers to tractors, investment costs per labour hours rises, but investment productivity declines. This is more so in rated terms when acquisition costs are used for computation (Column A, in Figure 7.2). Generalizations based on these unadjusted figures are unsound because of differences in the time of purchases and whether the machine was new or used. Therefore in Column B, we normalize our computations using the current market prices.

Table 7.7: Annual investment cost at prevailing interest rate of 8.05%[33] (TSH '000,000)

	MM_0	MM_1	EE_1	EE_0
OC1	Kubota	*Siam Kubota*	*Greeves*	*Amec*
Estimated life (years)	12.00	7.00	4.00	3.00
Annual investment cost 1	1.16	1.49	2.25	1.42
Annual investment cost 2	2.13	2.50	2.42	2.33
OC2			Farmtrac 45	Swaraj
Estimated life (years)			4.00	5.00
Annual investment cost 1			3.87	5.64
Annual investment cost 2			5.44	6.02
OC3	Valtra (Finland)	Massey Ferguson (Brazil)	Massey Ferguson (Pakistan)	
Estimated life (years)	12.00	10.00	5.00	
Annual investment cost 1	8.06	9.08	6.57	
Annual investment cost 2	8.65	10.16	6.52	
OC4	New Holland (EU)	Massey Ferguson (Brazil)	Farmtrac 70 (India)	
Estimated life (years)	10.00	10.00	4.00	
Annual investment cost 1	9.80	9.08	7.54	
Annual investment cost 2	10.46	10.16	7.56	
OC5	New Holland (EU)	New Holland (Turkey/Brazil)	New Holland (India)	YTO (China)
Estimated life (years)	10.00	7.00	5.00	3.00
Annual investment cost 1	9.80	9.74	11.19	8.78
Annual investment cost 2	10.46	10.58	11.54	9.32

MM- Matured Markets; MM_0- MM technologies made in MM; MM_1- MM technologies made in EE

EE- Emerging Markets EE_1-MM technologies adapted to EE; EE_0- EE technologies made in EE

Annual investment cost 1- based on historical cost Annual investment cost 2- based on replacement cost

Source: Field Survey, 2012/2013

The fact that different machines have different economic lives means that computing the efficiency ratios based on just the initial investment cost may give a distorted picture of

[33] This is the real interest rate in Tanzania during 2011/2012

reality. That is to say, for any two machines purchased at the same time and at the same price, if their economic lives are different, then their annual investment costs will also differ. Therefore in Table 7.7, investment costs are transformed into their annual equivalents[34] using the prevailing real interest rates of 8.05%. These adjusted (annualized) investment costs are then used to compute the efficiency ratios in Table 7.8 using both acquisition and replacement costs.

Table 7.8: Productivity ratios using annual investment costs (adjusted & unadjusted version)

	MM0		MM1		EE1		EE0	
Power tillers								
	Actual	Rated	Actual	Rated	Actual	Rated	Actual	Rated
OC1	Kubota		Siam Kubota		Greeves		Amec	
K_1/L	0.01	0.00	0.01	0.01	0.02	0.01	0.01	0.00
O/K_1	42.37	79.37	52.91	64.52	14.01	44.64	32.26	66.23
K_2/L	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.00
O/K_2	23.09	43.29	31.45	38.31	13.02	41.49	19.65	40.32
Tractors								
OC2					Farmtrac 45		Swaraj (India)	
K_1/L					0.03	0.01	0.04	0.03
O/K_1					38.76	121.95	36.23	52.36
K_2/L					0.05	0.02	0.04	0.03
O/K_2					27.55	86.96	33.90	49.02
OC3	Valtra (Finland)		MF (Brazil)		MF (Pakistan)			
K_1/L	0.08	0.02	0.11	0.02	0.07	0.02		
O/K_1	17.76	71.94	12.30	60.98	19.42	84.75		
K_2/L	0.08	0.02	0.12	0.02	0.07	0.02		
O/K_2	17.76	71.94	12.30	60.98	19.42	84.75		
OC4	New Holland (EU)		MF (Brazil)		Farmtrac 60 (India)			
K_1/L	0.06	0.03	0.07	0.03	0.08	0.03		
O/K_1	18.05	38.02	13.77	30.40	12.61	32.05		
K_2/L	0.06	0.03	0.08	0.03	0.06	0.02		
O/K_2	16.92	35.59	12.30	27.17	12.58	31.95		
OC5	New Holland (EU)		New Holland (Turkey/Brazil)		New Holland (India)		YTO (China)	
K_1/L	0.05	0.02	0.07	0.02	0.08	0.02	0.07	0.02
O/K_1	16.86	49.26	11.92	46.08	9.82	37.04	10.82	47.17
K_2/L	0.06	0.02	0.07	0.02	0.08	0.02	0.07	0.02
O/K_2	15.80	46.30	10.96	42.37	9.53	35.84	10.19	44.44

Ratios with subscript 1 uses historical costs and subscript 2 uses replacement costs for computation

MM- Matured Markets; MM_0- MM technologies made in MM; MM_1- MM technologies made in EE

EE- Emerging Markets EE_1-MM technologies adapted to EE; EE_0- EE technologies made in EE

Source: Field Survey, 2012/2013

[34] The formula for computing the annual investment cost (A) is given as $A = I/\left[1-\frac{1}{(1+r)^n}\right]/r$; where I= initial investment cost, r=interest rate and n=number of years.

b. Variable costs (fuel, lubricants, maintenance and labour)

The different techniques are associated with different running costs. The main running costs can be categorized into three: fuel and lubricants; maintenance (repair and spare parts costs) and; labour cost. These running costs are discussed in turn.

Estimates of fuel consumption were given by respondents on a per acre bases which was then converted into monetary values using the prevailing market prices per litre. The per annum equivalents were computed using the average work done per season by each category of machine. In the case of power tillers, though MM machines are more fuel efficient on a per acre basis than EE machines, the absolute amount of fuel consumed by the former per season is higher than the latter under OC1. This is expected because on the whole, and as stated when machine performance was discussed in earlier sections of this chapter, MM machines cultivated larger area per season than EE machines.

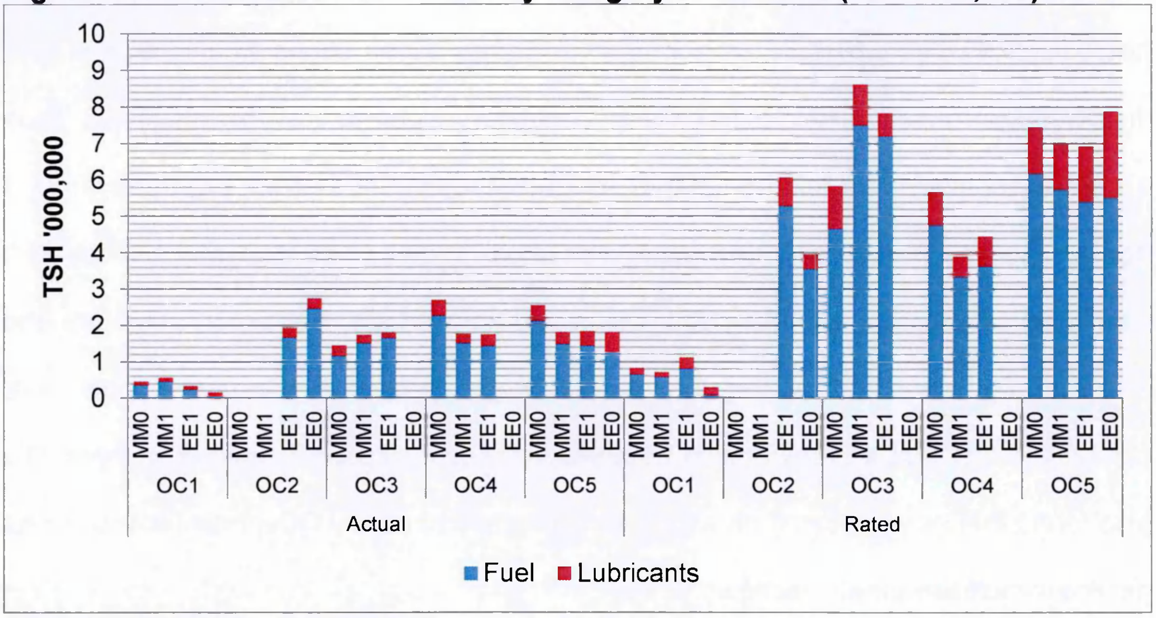
A similar relationship is observed for lubricant consumption. That is, power tillers which cultivated more acres per annum also consumed more lubricants both in actual and rated terms. Amec (EE_0) has notoriously high lubricant consumption because the engine over-heats due to leakages from both the gear box and engine especially in comparison with the total work done per season. Fuel consumption under the different OCs for tractors does not vary much per acre. However, lubricants consumption on the other hand does, (Figure 7.3).

The challenge of fuel consumption goes beyond the number of litres consumed per acre. Availability of quality diesel that is unadulterated is also important. Because of inadequate infrastructure, especially in rural areas, private businesses participating in the sale of fuel to tractor users do so in containers. Fuel stored under such conditions can easily be contaminated with dust. In other instances, there are suspicions by owners of tractors to suggest that sellers of diesel sometimes adulterate it with kerosene. Because the engines are not made to run on such combinations of diesel and kerosene, they tend to knock and get damaged quickly, warranting frequent repairs.

The bright spot in this rather imperfect supply of diesel is the recent improvements in the supply chain as a result of the booming motor cycle industry which has brought in market expansion and encouraged more rural entrepreneurs to sell diesel. For many farmers, it is their hope that the competition that is being bred by the surge in demand will eventually drive out sellers of low quality diesel products. In other developments, some repair shops reported that some of their clients do not know the right kind of lubricants to use. Even in instances where they do have the right knowledge of lubricants, the lubes are not changed on time. This puts an unnecessary stress on the engine and eventually reduces its lifespan. Repairers mentioned that for the more fragile EE machines, if strict adherence to lubrication instructions is not maintained, the likelihood of owners losing their engine parts earlier than expected is high. Users on the other hand argue that most Chinese machines come with instructions and manuals written in Mandarin. The preferred language for these manuals would have been Swahili, but in its absence, English would have been helpful.

An importer of a very popular EE tractor in Dar es Salaam who organises training for farmers buying new equipment from his shop was disappointed with regard to the response of farmers to training. He mentioned that for any new buyer, the company gave a -four day training programme to the owner and the operator especially on issues concerning routine maintenance. The company covers the full cost of the training, with the farmer paying for accommodation and feeding. However most farmers never attend the training and only come in and pick their machines once the financial transactions have been sealed. In his opinion, even if EE machines were as robust as MM ones, without training for users, they will not stand the test of time. This importer is very aware that their customers are at the bottom of the pyramid in terms of incomes and innovative ways should be pursued to help them overcome the financial constraints. This, he said his company in India is doing through cost reduction.

Figure 7.3: Fuel and lubricant costs by category of machine (TSH '000,000)



Source: Field Work, 2012/2013

Maintenance costs can be divided into two: the labour and transportation costs associated with getting the machine repaired or routinely maintained and the costs of spare parts and the transportation costs associated with accessing them (Figure 8.4). Generally, regardless of scale, repair charges were more expensive than spare parts for all brands of machines under the various operating conditions.

In both actual and rated terms, the Kubota (MM_0) power tiller was the most expensive to maintain per season compared with the other three power tiller makes under OC1. While it was relatively easier for users to access spare parts for Amec and Greeves, Kubota and Siam Kubota spare parts were very scarce. Thus aside from the actual cost of the spare parts, MM power tiller owners had the unpleasant experience of having to spend very expensive field days in search of spare parts when there is a breakdown, though breakdowns are not very frequent[35]. MM power tiller owners repaired their machines in workshops which were on average 2.9km from their home and significantly different (10% level) from EE power tiller users who had repair shops within about 1.8km radius from their home.

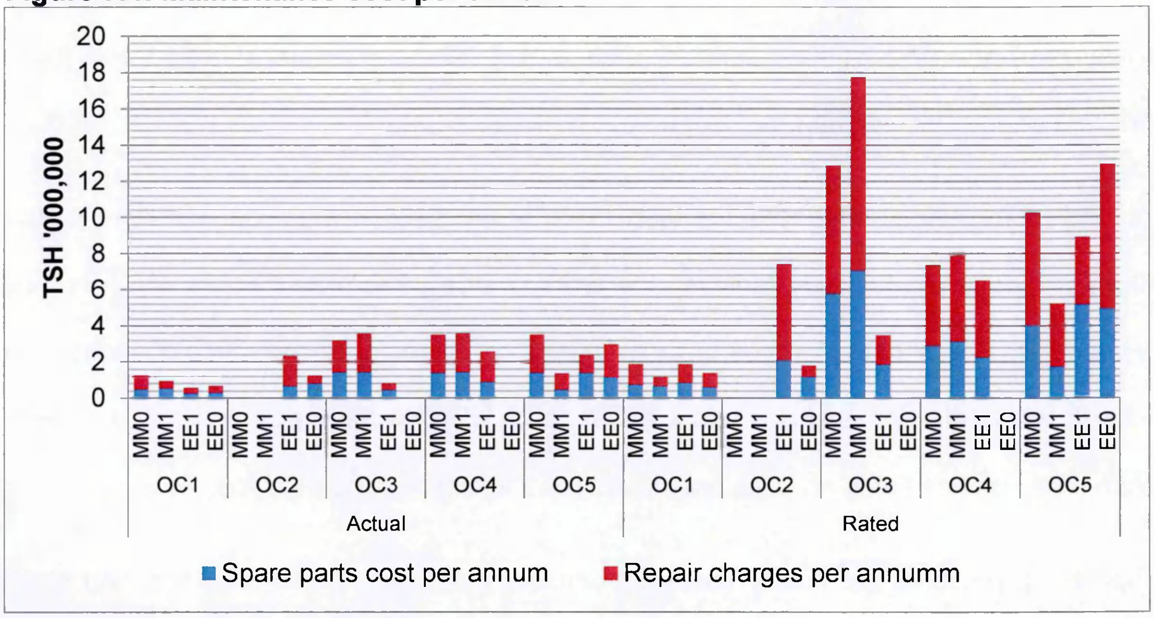
[35] Spare parts for Kubota were difficult to find all over the country. Siam Kubota spare parts were very difficult to find in the Mbeya area, but they were available in Babati

The tractor story was no different. MM users have to move from their home an average distance of 29.6km whilst EE tractor users had their repair shops located 8.2km from their home on average (this difference is statistically significant at the 1% level). Thus access to repairers was relatively easier for EE users than MM users. For tractors, YTO from China had the highest maintenance cost per annum, if operating at full capacity compared with the other brands, both within and across OCs. Repairers, operators and extension officers confirmed that though YTO was a good tractor in terms of the work output, the fact that it breaks down frequently makes it unpopular among farmers. We also found that as we move from sandy, through loam to clayey OCs, maintenance costs generally increase for all machines.

The issue of availability of spare parts for tractors is a daunting challenge for EE owners, mainly. However, for EE brands which have been modelled after MM ones, for example Massey Ferguson from Pakistan and New Holland from India, users simply buy spare parts from Europe or Brazil and use them. Users of Farmtrac and YTO especially face challenges of availability of spare parts. Distributors were very concerned about the situation and for one of them in the Morogoro area, plans were very advanced for a team from Tanzania to be sent to the Farmtrac plant in India to see if a deal can be secured for the regular supply of these spare parts.

Repairers spoken with during field interviews in 2012, especially those engaged with power tillers, revealed that though they charge higher prices for the repair of MM machines (usually as an insurance against the event of damaging a part), close to two thirds of their annual incomes are realized from the repair of EE machines. In their opinion, this is because the EE machines break down more often and users frequent their shops more during the land preparation stage than the MM machines. Some repairers however feared that because the EE machines were relatively simpler to repair, in future most operators will become conversant with how to fix most problems and this will have a negative impact on their revenue. Because of the frequent breakdowns of EE power tillers, apprentices learning the repair and maintenance trade had more room to build capability in EE machines than MM machines. Thus most mechanics are more familiar with how the EE power tillers work than the MM power tillers.

Figure 7.4: Maintenance cost per annum



Source: Field Work, 2012/2013

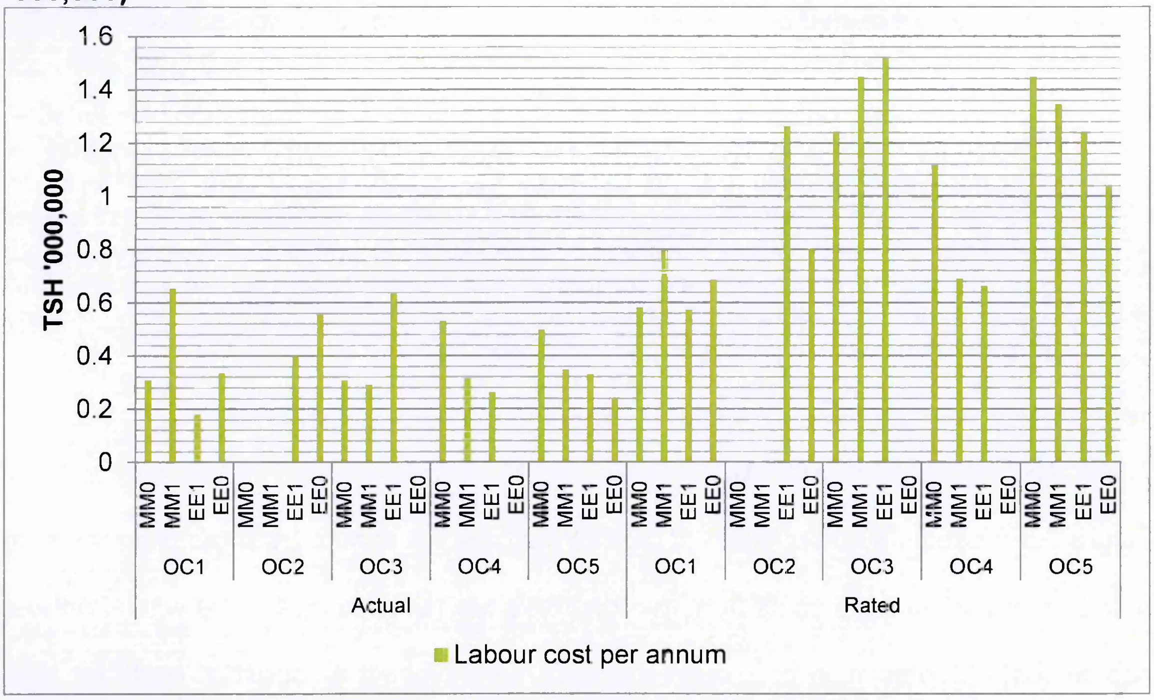
In the case of labour costs, there were two categories: managerial and operator costs. Whilst it was straightforward to get the price charged by the operator on a per acre basis and subsequently multiplying it with the total acreage ploughed during the season to get the annual version, it was very difficult and practically impossible to account for the costs associated with the owner managing the use of the machine. One way of going around this was to estimate the time committed by the owner to manage the machine for the whole season. And then find an appropriate compensation for them based on the prevailing minimum wage. The minimum wage approach was practically impossible because farmers could not specify how much of their time was used in managing the machine per season. In these analyses therefore, only the operator cost is included.

The wage rates per acre as reported by machine operators and owners are determined by a number of factors. First amongst these factors is the number of power tillers or tractors in the community. If there are so many machines around, then the amount of work each machine gets to do during the season declines significantly and so owners are unable to pay higher wages to operators and vice versa. Second, more experienced operators tend to work for owners with newer and more robust machines of MM origin. Thus for an older machine of EE origin which breaks down more often, as an incentive to attract a very good operator, owners must pay higher wages. This situation has led to many inexperienced workers operating EE power tillers, while experienced and more efficient ones work with MM machines.

A third factor which influences the wage rate is the type of machine: because power tillers are generally labour intensive, operators charge more than tractors which is less labour intensive. Finally the type of crop for which the tractor is cultivating the land also affects the wage. For example operators under predominantly maize farms charge less than those on rice fields and this presumably is a function of the soil type.

Figure 7.5 presents the labour costs per annum. For power tillers, in actual and rated terms, the labour cost is highest for Siam Kubota (MM_0) per annum, in comparison with the other three alternatives. Per season an operator working with Siam Kubota on paddy fields can potentially earn TSH800,000 if he works for 35 days. On maize fields in the Dodoma area and elsewhere, Farmtrac 45 (EE_1) operators earn over TSH1.2 million per annum in comparison with Swaraj (EE_0) operators who can earn a little over TSH 800,000. However considering the actual levels of income obtained by Farmtrac-45 operators in relation to their rated levels, Swaraj operators actually earn higher wages per annum under the current operating conditions. Under maize and tobacco fields (in Iringa and Babati, OC3), Pakistani Massey Ferguson wages are higher (a little over TSH 1.5), than Massey Ferguson from Brazil and Valmet from Finland.

Figure 7.5: Labour cost under the different operating conditions per annum (TSH '000,000)



Source: Field Work, 2012/2013

Under OC4, typically found in Mbeya and Morogoro, operators of New Holland Tractors from the EU (MM_0) have a potentially higher opportunity to earn more than their counterparts operating MF from Brazil (MM_1) or Farmtrac 70 from India (EE_1). Under OC5, operators of New Holland, EU (MM_0) earn higher wages than those operating New Holland, Turkey ((EE_1) both in actual and rated terms. In the same vein, operators of New Holland from India earn less than those operating New Holland from Turkey, though their earnings are higher than operators of YTO from China. In as far as MM machines tend to attract more experienced operators, although the EE operators generally earn less than their MM counterparts, it gives them an opportunity to improve their skills. There is therefore a trade-off between wage rates and the opportunity for capability building and skill development. However in terms of the performance of the machines, the lower quality nature of the EE operators could be affecting how well the machines are treated and consequently accentuating the level of breakdown frequency and cost of repairs. For instance, an inexperienced operator may not know the exact time to change the oil, or refill the water tank of the cooling system. This may affect the performance of the machine. As suggested by an engineer in charge of Suma JKT workshops:

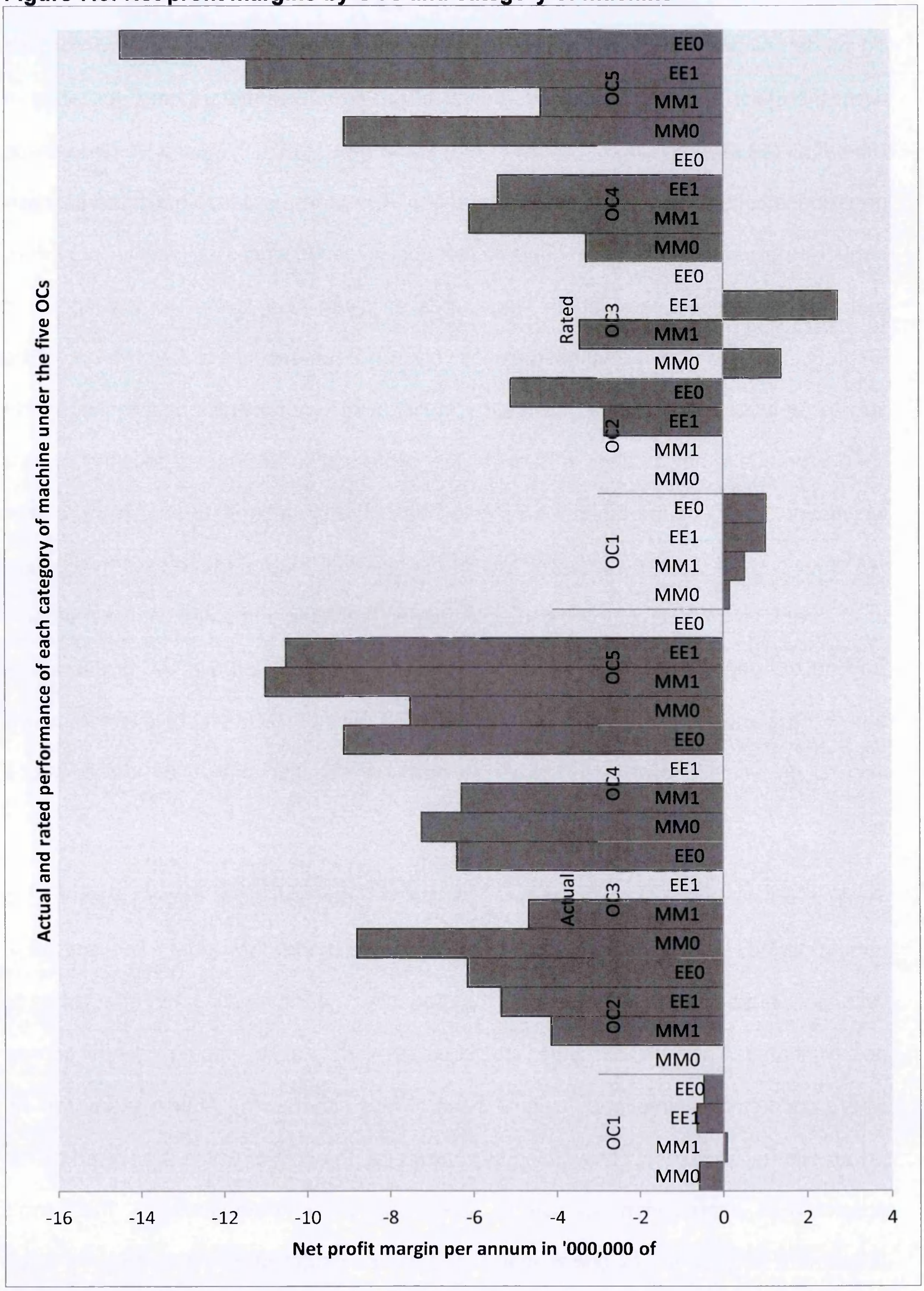
> "...in the Tanzanian situation where capital is scarce, cost innovation is inevitable. Though innovating in the cost sense may sacrifice some level of quality, if operators are properly trained to know the depth, speed and draft force to operate, maybe some of these Indian and Chinese machines may last longer than they do today...it will however be interesting to know how much it costs to train an operator properly as compared with quality reduction in machines to make them affordable and which way we should look as a country..." (Key informant interview with SUMA-JKT engineer, 2012).

7.5.4 Net revenue per annum

Figure 7.6 presents a computation of the net margins per annum by subtracting the sum of the fixed and variable costs from the total revenue per annum. On the whole, annual capital costs (depreciation or investment cost) ranks highest amongst all costs for both power tillers and tractors, regardless of the category (whether MM or EE). This is followed by repair and maintenance, fuel and lubricants and then by labour cost. In detail, we find that aside from Siam Kubota, none of the power tillers posted positive margins in actual terms per annum[36]. However, under full employment during the season, all four power tillers have the potential of posting positive margins. Taking output into account, the estimates also suggests that for power tillers, MM_1 versions are the most expensive to run per annum whilst for tractors, MM_0 is found to be the most expensive. In the same vein, for both tractors and power tillers, EE_1 versions are the least expensive to run per annum.

[36] However these technologies are still diffusing suggesting that the neo-classical economics do not always capture the reasons for choice of technology

Figure 7.6: Net profit margins by OCs and category of machine



Source: Field Work, 2012/2013

7.6 Rates of return: dynamic optimality

To model investments in agricultural mechanisation services (own farm and contract hire), the study adopted a modified version of the firm investment theory described in Diao et al. (1998) (see also Kaplinsky (1990) and Stewart (1977)). Mechanisation service provision is considered a business run by a firm. The firm's goal is to maximize its inter-temporal net profit π, taking existing capital costs, market prices for service provision, fuel and other inputs, and labour wage rates as given (that is the various input and output variables we have discussed extensively in the sub-sections before this one). The firm as an investor decides between either a tillage service business by investing in the various brands of power tillers or tractors. The opportunity cost of doing so is the interest which would have been earned if the money was saved in a bank. In principle, the farm will only invest in a particular power tiller or tractor when the returns to such investment are higher than the interest to be earned on saving the same amount of capital in a bank. Beyond the decision to invest, the farmer must choose between a range of alternative power tillers and tractors (MM_0, MM_1, EE_1 and EE_0). This decision among alternatives will depend on which one of them brings the most benefits (income) in an inter-temporal sense.

Thus, it is assumed that once the farm invests in a power tiller or tractor, it lasts for a certain period, *n* years depending on the source and brand (MM_0, MM_1, EE_1 and EE_0). With the required annual maintenance, the productivity of the tractor is not affected by its depreciation (an assumption which could be relaxed in a developing country context where such strict maintenance culture is not always adhered to). After n years, the old power tiller or tractor will be replaced by a new one, the cost of which is covered by the accumulated depreciation as part of investment profit. Mathematically, this farm's investment decision in any one n-year period can be modelled as maximizing the value of the following equations:

$$\pi = \sum_{t=1}^{n} R_t G_t - I \qquad (7.1)$$

$$R_t = \frac{1}{(1+r)^t} \qquad (7.2)$$

where π is the total discounted net profit over n years (as the power tiller or tractor's lifetime has been shown to vary according to the source and brand), Rt is the annual discount factor, r is the annual saving interest rate (real interest rate), and I is the actual power tiller or tractor cost paid by the farm initially, assuming that the farm invests its own money and ignoring the cost of borrowing. Gt is the gross margin for the farm (that is, the annual service provision revenue minus variable costs). The gross margin in year t can be estimated as follows:

$$Gt = P * At - At(F + L) - M \quad - (7.3)$$

Where P is the market-determined tillage service charge per acre, A_t is the acreage tilled, F represents the fuel and lubricant costs per acre, L represents the labour costs per acre, and M represents the maintenance and repair costs per year. P, F, L, and M are assumed to be constant over time. Solving this inter-temporal profit maximization problem by taking into consideration capital depreciation yields the following condition:

$$G = \delta I = rI \qquad - (7.4)$$

Where δ is the capital depreciation rate. Equation 7.4 indicates that the condition requires that the gross margin G minus the annual depreciation cost of the tractor investment equals the interest earned from saving the same capital at a bank. At this equilibrium point, the investor is indifferent between investing in a tractor and saving. Given that once the investment in the power tiller or tractor is made, the farm cannot sell it and save the capital, equation 7.4 needs to hold over the entire time horizon of n years, although it may not hold in each of the n years. To simplify the analysis, however, we assume that $A_1 = A_2 = \ldots = A_n$ and r is constant, so that equation 7.4 holds for each year. In other words, to make power tiller or tractor investment more attractive than simply earning annual interest from savings, the profits from power tiller or tractor service provision (own farm and contract hire) minus tractor annual depreciation cost must be higher than the returns (interest) from saving the capital (tractor investment cost) at a bank in each year. And again for the choice between different categories of tractors and power tillers, a ranking of these profits must be done.

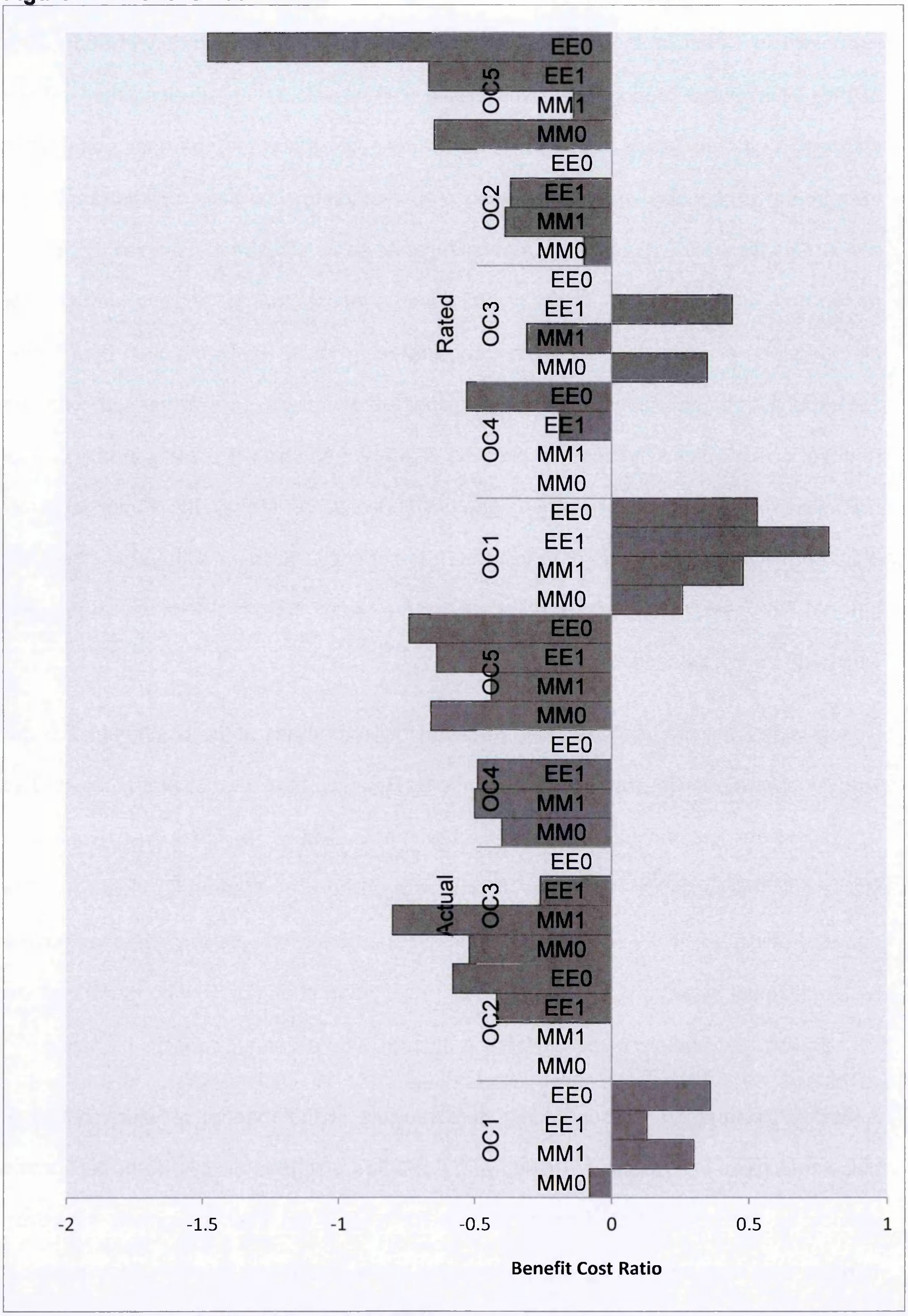
Let N = G – (r-δ) define the annual net profit from investing in a power tiller or tractor—that is, the profit minus the interest earned from saving the capital. Substituting the right-hand side of equation (3) for G yields:

$$N = P * A - A(F + L) - M - (r + \delta)I. \quad \text{- (7.5)}$$

Given P, F, L, M, r and δ, the net profit N depends on two key factors: the acreage tilled, A, and the initial investment, I. Based on these discussions we generate the NPV (discounted streams of benefits and costs) and the BCR (ratio of the NPV to I) in Figure 7.7 and 7.8.

All power tiller categories had a positive NPV and consequently BCRs were also greater than 0, when costs and benefit streams are discounted with the real interest rate of 8.05% in the rated sense. Computations based on actual work done using power tillers for the season under consideration also revealed that apart from Kubota (MM_1) all the other brands had a positive NPV. Analyses for tractors from OC2 to OC5 revealed a gloomier picture: generally, aside from the potential computations for MM_0 and EE_1 under OC3, all other NPVs for all tractors are negative. This suggests that under the current interest rates, most tractors operating under current factor prices and the value for an acre of land tilled cannot break even, despite government subsidies.

Figure 7.7: Benefit-Cost Ratios



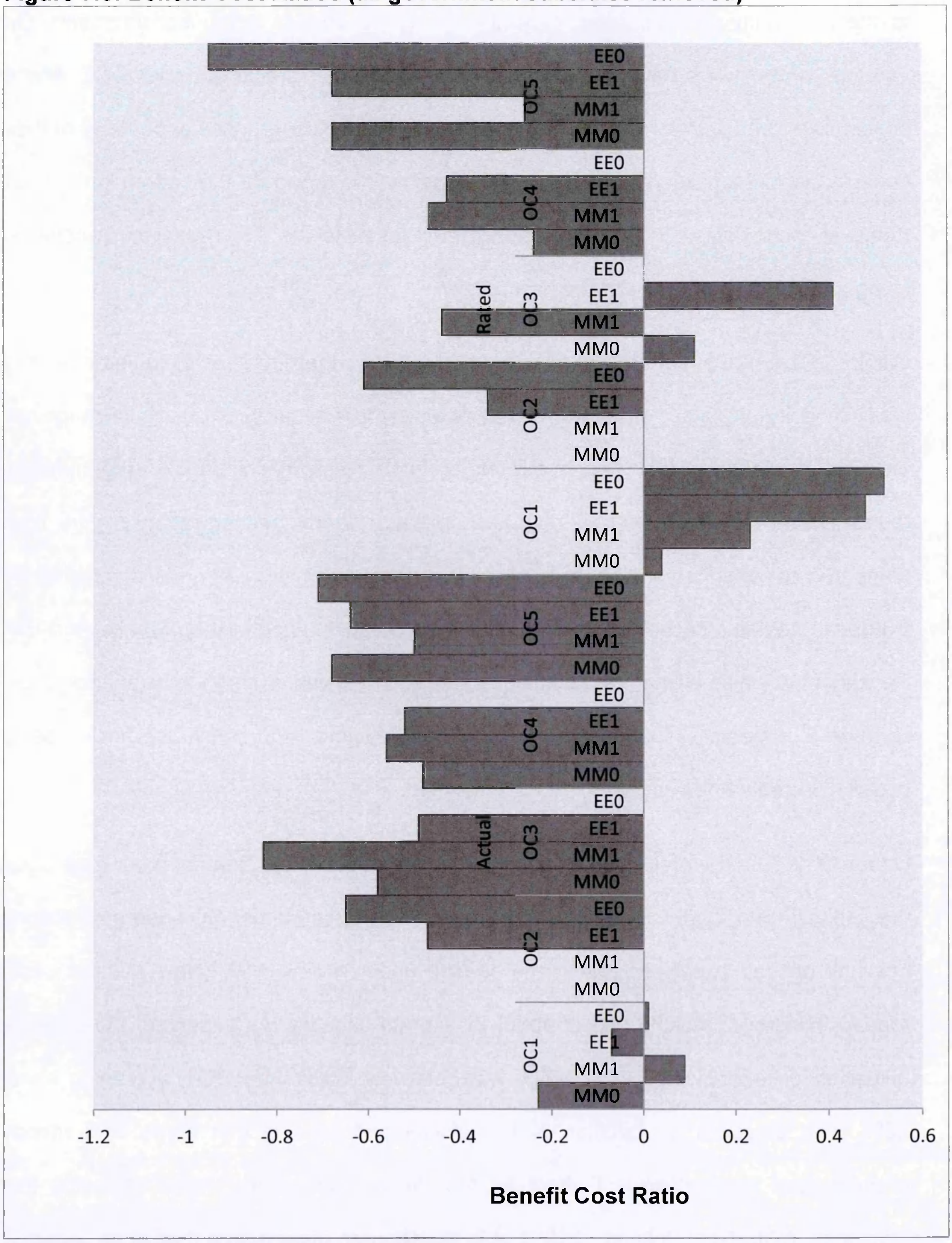
Source: Author's computation, 2012/2013

We also noted in Chapter 6 that there are government subsidies on imported farm machinery in Tanzania, including power tillers and tractors. An import duty of about 20% of the value of the product is waived and a VAT of about 17% is also taken off the acquisition cost. In Figure 7.8, we re-impose these taxes and test the outcomes on the investment profitability measures assuming marketing margins of importers and distributers were 10% (this is a modest estimate as some industry players say it could be as high as 30%) of the total price. This scenario suggests that for power tillers NPV for all categories of technologies declines considerably, but all BCRs maintain their signs. As expected, the profitability of tractors under the various OCs worsened with the removal of subsidies. This may confirm the belief of many tractor owners in our sample that running a tractor hiring service, whether you have an MM or EE tractor is purely philanthropic or at best is done to increase the capacity utilization. Otherwise, the main source of repayment for tractors especially, is the benefit from crops grown on the land which the tractor helps to cultivate.

Nevertheless, the predominantly negative profitability of many of the technologies under study is consistent with the findings obtained by Houssou et al. (2013) when they studied tractor hire services in Ghana. They found that mechanisation service provsion was not a viable business and that most large tractors are unlikely to make profit because of low capacity utilisation. They suggested that smaller tractors which are low cost may have a better potential in terms of profitability. See also Paman et al. (2010) who found that low cost and smaller tractors helped owners in Indonesia to realise full capacity utilisation.

A further explanation for our finding here may lie in the manner in which output is calculated here. We do this by multiplying the acres ploughed on own farm and rented service by the price which farmers charge for renting out their equipment. However, farmers may only be renting out their power tillers or tractors to cover their marginal costs and something extra to contribute to their fixed cost which has already been borne. And so the output figures may well be underestimated. This potential underestimation of output does not however sacrifice the relative profitatabilities of the various technologies, since any bias here is purely systemic and not limited to particular technologies.

Figure 7.8: Benefit-Cost Ratios (all government subsidies removed)



Source: Author's computation, 2012/2013

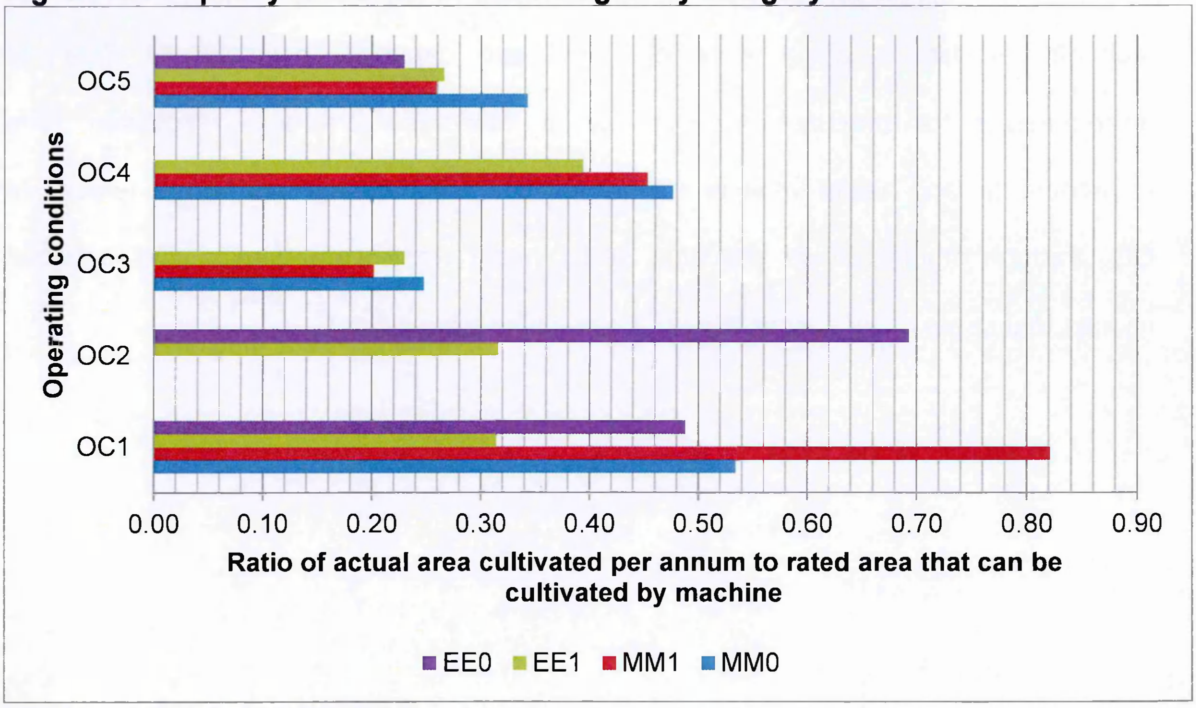
7.7 Capacity utilisation

Figure 7.9 presents the annual capacity utilization of the various technologies under the five distinct OCs. The computation here is a ratio of the actual number of acres cultivated to the maximum possible rated capacity during the season under consideration. On average, power tillers have higher capacity utilization than tractors. Under OC1, where power tillers are used, MM_1 machines (specifically Siam Kubota) uses about 82% of their capacity per annum, representing the highest within the group. At the bottom in the OC1 range of technologies in terms of capacity utilization is the EE_1 (Greaves) machines, using about a third of their capacity per annum.

Within OC2 to OC5, where tractors are used, we find that OC3 technologies have the least capacity utilization on average. The relatively low capacity utilization of machines under OC3 could be explained in two ways. First, these machines are predominantly found in areas of the country (Iringa and Babati) where mechanisation is very high compared to other regions as a result of large scale commercial farms dominated by European settlers. Second, there has also been a recent supply side push by Agri-Pak Tanzania Ltd which is importing machines made in Pakistan. Thus there is a stock of old reliable European, Japanese and American tractors and they are now being complemented by new entrants from EE markets.

Under OC2, EE_0 (Swaraj) uses close to 70% of its capacity per annum, more than twice the capacity used by EE_1 (Farmtrac 45). Technologies used under OC4 operated around one-half of their capacities during the season under review. MM_0 (New Holland - EU) topped the group; making use of about 57% of its capacity. As expected, the capacity utilization of technologies under OC5 was relatively lower than OC4, averaging about 25%. The plausible explanation is the challenging terrains that come with muddy grounds and the consequent effect on the tractor down times. Notwithstanding this challenge, MM_0 (New Holland - EU) is able to use up to more than a third of its capacity, signalling their relative suitability for such conditions compared to the others.

Figure 7.9: Capacity utilization of technologies by category and OCs



Source: Authors computation

7.8 Conclusion

This chapter has established the economic optimality of the various categories of technologies, by the use of the productivity ratios and the NPV ratings. In the next chapter we would want to know why sometimes users choose unprofitable techniques. To do this we first discuss the factors which influence choice. These factors are broadly grouped into four: characteristics of the technology itself (cost, quality and efficiency); characteristics of the market (sales, service, spares, finance, information and propensity for contract hire), characteristics of the farm (farm size, crops, farming system and distance to main market) and the farmer (age, income, family size, education, member of cooperative group, extension contact and view about emerging market products).

To bring our discussion home to optimal technology and inclusive innovation through growth and distribution to excluded portions of society, we discuss in the next chapter the extent to which the choice of various techniques impact on employment and outputs and who benefits from these. Growth in farm size and output, as well as which types of crops (cash crops or food security crops) benefit most from different categories of technologies. Issues about ease of repair and capability development, financial arrangements for procurement and gender outcomes are also discussed. The environmental and health impacts are not left out: emphases is laid on the release of CO_2 through smoke, noise pollution, scrap metal waste, ergonomics and potential injuries that users could sustain during the machine's operation.

Chapter 8 : Economic Profitability, Diffusion and Social Optimality

8.1 Introduction

This chapter first of all establishes the relationship between physical coefficients, economic profitability and diffusion in Section 8.2. An attempt is made also to explain why sometimes economically inefficient or socially inappropriate technologies are selected and diffused at the expense of more desirable ones. In Section 8.3, an examination of the social appropriateness of the different techniques is undertaken. Here attention is paid to output, employment, incomes and human capital development outcomes. In Section 8.4, the discussion touches briefly on some aspects of environmental impact, health and user satisfaction with the two sources of technologies. Some chapter conclusions are then made in Section 8.5 with the view of drawing an overall implication for policy.

8.2 Physical ratios, return on investment and diffusion of technologies

If the object of ranking projects and industries is to explore their employment generating capacity, then the share of employment in total, that is the absolute size, is as relevant as the ratios that reflect labour intensity (Bhalla, 1981). The Benefit-Cost Analyses which generates some measure for the relative rates of return on investment is also essential for the decision maker (who in this case is the Tanzanian farmer) to make a choice amongst alternative technologies under different operating conditions (Kaplinsky, 1981). In addition, capacity utilization levels are also crucial information for the farmer, since they have implications on employment and output (Stewart, 1977). In Table 8.1, the four sub-categories of technologies are ranked according to the size of employment, the three indices of labour intensity, BCR and capacity utilization. Under each OC, every sub-category of technology is ranked between 1 and 4 for employment, productivity ratios and BCR. Here, the higher the rank the more labour intensive that technology is. The rankings are presented for both actual performance and rated capacity of the machine.

Under OC1 where power tillers are used on small scale rice fields which are predominantly clayey, in actual terms, EE_0 (Amec) rank highest for total employment and for all the three productivity ratios signifying a higher labour intensity compared with the other technologies.

This observation generally remains the same under full capacity utilization of the machine, except total employment in which Amec ranks the least. Under full capacity utilization, EE_1 (Greaves) out-performs MM_1 (Siame Kubota), which followed Amec for actual performance. Though MM power tillers have higher capacity utilization than EE ones, on average their Benefit-Cost-Analyses (BCA) are rated higher than the MM machines.

Comparing EE_1 (Farmtrac-45) and EE_0 (Swaraj) under OC2 where maize and pulses are grown on mainly sandy soils, the former ranks higher than the later for all the labour intensity indices and for the BCA than the later. Nevertheless, the capacity utilization of EE_0 is higher than the EE_1. This suggests that higher capacity utilization does not necessarily increase employment intensity or profitability under OC2.

Apart from size of employment, EE_1 machines (Massey Ferguson- Pakistan) rank higher than the other alternative technologies for all the coefficient of production estimation under OC3. Again the same category of tractors posted the highest rank in terms of BCA. However, MM_0 machines had higher capacity utilization under OC3 than other technologies in the same group.

Under OC4, labour intensity indices are in favour of EE_1 (Farmtrac-60). However MM_0 (New Holland- EU) ranks highest in terms of total labour employed per annum, profitability based on the BCA and capacity utilization. Under OC5, EE machines are predominantly labour intensive, but the same cannot be said of the profitability and capacity utilization.

Table 8.1: Ranking of technologies by employment, labour intensity, benefit-cost ratio and capacity utilization

Agro-economic condition (Soils and Crops)	Tech Category	Brand	*Rep Cost	Acres / man hour	Net income	NPV	Employment and production co-efficient. Actual (Rated)				BCR Actual (Rated)	Capacity utilisation
							EMP	K/L	O/L	O/K		
OC1: Rice on small scale clay fields	MM0	Kubota-Japan	4	3	3(1)	1(2)	2(2)	1(1)	1(2)	1(1)	1(1)	3(0.53)
	MM1	S. Kubota-Thailand	3	4	4(2)	4(3)	1(3)	3(2)	3(1)	3(2)	3(2)	4(0.82)
	EE1	Greaves-India	2	2	1(4)	2(4)	3(4)	2(3)	2(3)	2(3)	2(3)	1(0.31)
	EE0	Amec- China	1	1	2(4)	3(1)	4(1)	4(4)	4(4)	4(4)	4(4)	2(0.49)
OC2: Maize on small, medium & large scale sandy fields	MM0	_					.	.	.	.	.	.
	MM1	_					.	.	.	.	.	.
	EE1	Farmtrac 45-India	1	2	2(1)	2(2)	2 (2)	2(2)	2(1)	2(1)	2(2)	1(0.32)
	EE0	Swaraj-India	2	1	1(2)	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	2(0.69)
OC3: Medium to large scale maize & tobacco on loamy soils	MM0	Valtra- Finland	2	3	1(2)	2(1)	3(2)	2(2)	2(2)	2(2)	2(1)	3(0.25)
	MM1	MF- Brazil	3	3	2(1)	1(2)	1(2)	1(1)	2(2)	1(1)	1(2)	1(0.20)
	EE1	MF- Pakistan	1	1	3(3)	3(3)	2(3)	3(3)	3(3)	3(3)	3(3)	2(0.23)
	EE0	_	.	.			.	.	.	.	.	.
OC4: Upland sugar and rice on clay (small, medium and large scale)	MM0	New Holland-EU	3	3	2(1)	2(3)	3(2)	2(2)	2(2)	2(2)	3(3)	3(0.48)
	MM1	MF- Brazil	2	2	3(3)	1(1)	2(1)	1(1)	2(2)	1(1)	1(1)	2(0.45)
	EE1	Farmtrac 60- India	1	1	1(2)	3(2)	1(3)	3(3)	3(3)	3(3)	2(2)	1(0.39)
	EE0	_	.	.			.	.	.	.	.	.
OC5: Irrigated sugarcane and rice on clay (small, medium and large)	MM0	New Holland-EU	4	4	2(2)	1(1)	4(3)	2(1)	1(3)	2(1)	2(3)	4(0.34)
	MM1	New Holland-Turkey	3	3	1(1)	3(4)	2(4)	1(2)	2(4)	1(2)	4(4)	2(0.26)
	EE1	New Holland- India	2	2	4(3)	2(3)	3(3)	3(3)	3(3)	3(3)	3(2)	3(0.27)
	EE0	YTO- China	1	2	3(4)	4(2)	1(3)	4(4)	3(3)	4(4)	1(1)	1(0.23)

**Replacement cost*

Source: Field Work, 2012/2013

Depending on the endowments of users, either labour intensive or capital intensive technologies will be economically optimal (Clark, 1985). That is in societies where labour is abundant, technologies which economise on capital might be expected to be favoured and vice versa (Cooper & Kaplinsky, 1975). Assuming perfectly competitive markets, profitable technologies are likely to be transferred, distributed and diffused among users more than unprofitable ones in comparative terms. The profitability of any technology is influenced by the engineering efficiency and the input and output prices. Assuming our analyses of physical coefficients of capital, labour and output were correct, and NPV and BCR computations in the previous chapter were a true representation of reality in Tanzania, we expect that for profit maximizing households, power tillers and tractors which give the highest profit will be accessed and used under the different OCs.

In the same vein, for importers and distributors, attention is likely to be given to developing a value chain for technologies which users want to buy and not what they have to offer. An overarching constraint that might influence the technologies which have a better chance of being distributed is finance, especially in a developing country context where the cost of capital is very high. The challenge of finance is thus not only a user constraint but also an importer one.

In the sub-sections which follow we examine how productivity ratios and returns on investment influence technology diffusion and the extent of use. Possible explanations for why profitable technologies (in the economic sense) may not be diffused or otherwise are also presented. The discussions here draw on the rankings presented in Table 8.1 above and extend the ranks to cover the level of penetration[37] of each of the technologies. The higher the rank, the higher the penetration level of the technology within the country.

[37] Based on casual empiricism and data from the Mechanization Department of Tanzania

8.2.1 Relationship between coefficients of production and diffusion

With increased output as a desired objective, the area cultivated by each technology is just as important as how efficiently it is done. But here as mentioned earlier capital saving technologies are more desirable especially for the poor. For relatively richer producers, technologies which complete work on time may appeal more than those which save on capital. In other instances, the nature of the soil and scale of operation will not permit the use of low quality machines- high quality, high cost becomes an inevitable choice. We examine these foundations under the various OCs in turn.

Under OC1 as shown in Table 8.2, the Thai Siam Kubota cultivates the largest area per season. It is however the most capital intensive after the Japanese Kubota. It is the second most diffused technology on small paddy rice fields. The Chinese Amec which has the lowest capital intensity and the highest capital efficiency is the most diffused. It also employs the highest labour hours per annum, but sits nearly at the bottom of the rankings in terms of area cultivated which is essential for total farm output. The point here is that though Chinese Amec does not cultivate an area as large as the Thai Siam Kubota, it is more popular among low income farmers because their farms are relatively smaller and they may not need the higher capacity offered by the Siam Kubota. However if growth in farm output is desired, then this ought to be of concern, since higher capacity is required for expanding the area under cultivation.

Table 8.2: Coefficients of production and diffusion, OC1

OC1: Power Tiller	Source	Brand	Area	Employment & production coefficients				Technology Diffusion
				EMP	K/L	O/L	O/K	
Rice on small scale clay fields (12-24Hp)	MM_0	Kubota-Japan	3	1	**4**	3	1	1
	MM_1	S. Kubota-Thailand	**4**	3	3	**4**	3	3
	EE_1	Greaves-India	1	2	2	2	2	2
	EE_0	Amec- China	2	**4**	1	1	**4**	**4**

Area- area cultivated with machine per annum; EMP- Total labour hours employed per annum K- Capital; L- Labour; O- Output

**Rank 4 is Highest and Rank 1 is Least Best;

Source: Author's computation, 2012/2013

Farmers cultivating maize or sometimes millet and pulses on generally sandy soils under OC2 have access to two groups of tractors with a current functioning market. The other markets like second-hand Fiat, Massey Ferguson and SAME from the EU have suffered a decline as a result of the lack of financial institution support and a higher demand for them by Eastern Europeans. Second-hand versions of these brands of between 25 to 49Hp are not available in the volume they used to be. Thus we have Farmtrac-45 and Swaraj, both of Indian origin dominating the market. Swaraj cultivates a larger area and also employs more people per annum than Farmtrac-45. Farmtrac-45 is more capital intensive, and possesses a relatively higher labour and capital productivity than Swaraj. Notwithstanding this superior performance of Farmtrac-45 in terms of labour and capital productivity, Swaraj is more popular among users in the study area. Factors that might have influenced this diffusion pattern include the fact that aside from Swaraj having a simpler engine technology, the sales, service and spare parts depot is closer to users than Farmtrac-45. See Table 8.3.

Table 8.3: Coefficients of production and diffusion, OC2

OC2: Tractors	Source	Brand	Area	Employment & production coefficients				Technology Diffusion
				EMP	K/L	O/L	O/K	
Maize on small,	MM_0	_	.	.	.	.	.	.
medium & large	MM_1	_	.	.	.	.	.	.
scale sandy fields	EE_1	Farmtrac 45-India	1	1	**2**	**2**	**2**	1
(25-49Hp)	EE_0	Swaraj-India	**2**	**2**	1	1	1	**2**

A- Area cultivated with machine per annum; EMP- Total labour hours employed per annum K- Capital; L- Labour; O- Output

**Rank 2 is Highest and Rank 1 is Least Best;

Source: Author's computation, 2012/2013

Table 8.4 compares Valtra (Valmet), Massey Ferguson (Brazil) and Massey Ferguson (Pakistan) on maize and tobacco farms intercropped with vegetables or sunflower. It is clear from the rankings that Valtra cultivates the highest number of acres per annum, creating the highest level of employment under OC3 in relative terms. The same tractor also competes head-to-head with Massey Ferguson (Brazil) with respect to highest labour productivity in the group. On the other hand, Massey Ferguson (Brazil) is the most labour intensive, and it also comes as no surprise as the most diffused because of its long standing history on farms. However the long standing use of the Massey Ferguson brand, (which was originally being imported from UK and now from Brazil) in Tanzania may be the main driver of these diffusion levels. Massey Ferguson (Pakistan) is the most efficient in terms of output-capital ratio and yet the least diffused - It has only been on the market since 2010. It is expected that with the current interest shown by farmers and farmer groups, if some of the quality issues affecting the machine are addressed it could dominate the market in the near future.

Table 8.4: Coefficients of production and diffusion, OC3

OC3: Tractors	Source	Brand	Area	Employment & production coefficients				Technology Diffusion
				EMP	K/L	O/L	O/K	
Medium to large scale maize & tobacco on loamy soils (50-65Hp)	MM_0	Valtra- Finland	**3**	**3**	2	**3**	2	2
	MM_1	MF- Brazil	1	1	**3**	**3**	1	**3**
	EE_1	MF- Pakistan	2	2	1	2	**3**	1
	EE_0	_	.	.	.	.	.	.

A- Area cultivated with machine per annum; EMP- Total labour hours employed per annum K- Capital; L- Labour; O- Output

**Rank 3 is Best and Rank 1 is Least Best;

Source: Author's computation, 2012/2013

Under OC4, Massey Ferguson (Brazil) with its earlier versions from UK are the most diffused and comes through as the most capital intensive and labour productive - though it shares the highest rank with New Holland (EU) in terms of labour productivity. Farmtrac-60 is the most capital efficient, producing the highest level of output per unit of capital. Farmtrac-60 is however the least diffused. Though there have been a recent surge in the distribution of Farmtrac-60, it is only as a result of central government subsidies. Under capital constrained conditions, one would have also expected that Farmtrac-60 would have been the most diffused under OC3, but it is not. In the past, it has been out-competed by second-hand Massey Fergusson from the UK and Poland because of its high breakdown frequency. See Table 8.5 for a presentation of these rankings.

Table 8.5: Coefficients of production and diffusion, OC4**

OC4: Tractors	Source	Brand	Area	Employment & production coefficients				Technology Diffusion
				EMP	K/L	O/L	O/K	
Upland sugar and rice on clay (All farm sizes) (65Hp+)	MM_0	New Holland-EU	**3**	**3**	2	**3**	2	2
	MM_1	MF- Brazil	2	2	**3**	**3**	1	**3**
	EE_1	Farmtrac 60- India	1	1	1	1	**3**	1
	EE_0	_		.	.	.	.	

A- Area cultivated with machine per annum; EMP- Total labour hours employed per annum K- Capital; L- Labour; O- Output

**Rank 4 is Best and Rank 1 is Least Best;

Source: Author's computation, 2012/2013

With respect to OC5 in Table 8.6, it was observed that in recent times New Holland (India) dominates as the most diffused across the entire landscape. But what is diffused here also depends more on the type of farmer. Relatively lower income farmers go in for the New Holland (India), while those wishing to upgrade after using the Indian type purchase and use the New Holland (Turkey). For large scale commercial farms, New Holland (EU) is common. Under OC5 where sugar cane and rice are produced on irrigated fields, New Holland (EU) does more work per annum, employs more labour hours and also has the highest labour productivity compared with the rest. Though YTO-China is the most capital efficient, it is the least diffused - the high breakdown frequency and absence of a well-functioning spare parts supply market might have influenced this pattern of diffusion.

In general, the productivity of capital in under most OCs tends to favour EE_0 machines. However, the total area cultivated which is a key variable to be considered when targeting growth in output tends to be higher for MM machines. Thus while the level of output per a unit of EE tractors or power tillers are higher relative to MM ones, total output in terms of area tilled is relatively lower.

Table 8.6: Coefficients of production and diffusion, OC5

OC5:Tractors	Source	Brand	Area	Employment & production coefficients				Technology Diffusion
				EMP	K/L	O/L	O/K	
Irrigated sugarcane and rice on clay (All sizes) (65Hp+)	MM_0	New Holland-EU	**4**	**4**	3	**4**	2	3
	MM_1	New Holland-Turkey	3	2	**4**	3	1	2
	EE_1	New Holland- India	2	3	2	2	3	**4**
	EE_0	YTO- China	1	1	**1**	2	**4**	1

A- Area cultivated with machine per annum; EMP- Total labour hours employed per annum K- Capital; L- Labour; O- Output

**Rank 4 is Best and Rank 1 is Least Best;

Source: Author's computation, 2012/2013

8.2.2 Economic profitability and diffusion

Table 8.6 ranks the various techniques under the different OCs using the Benefit-Cost-Ratio (BCR), capacity utilization and diffusion. In the same table, some reasons are assigned for instances where profitability and diffusion levels do not go together.

As stated earlier, economically profitable technologies should naturally penetrate more than less profitable ones. However, aside from OC1 where the most profitable power tiller (using the BCR measure) doubles as the most diffused technology, all other OCs do not show such correlations. Under OC1, Amec from China has the highest BCA, and also tops the national statistics in terms of diffusion. In terms of capacity utilization however Amec is second from the bottom. OC2 presents a criss-cross relationship between BCA and diffusion. That is, though Farmtrac-45 is the most profitable and has lower capacity utilization, Swaraj has a higher level of penetration. Whilst Massey Ferguson (Pakistan) is the most profitable according to the BCA computations, Valtra has the highest capacity utilization when OC3 is considered. Nonetheless, Massey Ferguson (Brazil) and its earlier variants from UK are the most diffused here. This evidence supports the argument that profitable technologies do not always get diffused. This is a key point which will be examined in detail per each OC in the following discussions.

Table 8.7: Economic optimality and diffusion**

Agro-economic condition (Soils and Crops)	Tech	Brand	BCR	Capacity utilisation	Tech Diffusion	Suggested reasons for diffusion outcomes
OC1: Power Tiller Rice on small scale clay fields (12-24Hp)	MM0	Kubota-Japan	1	3	1	None
	MM1	S. Kubota-Thailand	3	**4**	3	
	EE1	Greaves-India	2	1	2	
	EE0	Amec- China	**4**	2	**4**	
OC2: Tractors Maize on small, medium & large scale sandy fields (25-49Hp)	MM0	_	.	.	.	Availability of machine spare parts, as well as the reliability of engine of Swaraj most diffused though not the most profitable
	MM1	_	.	.	.	
	EE1	Farmtrac 45-India	**2**	1	1	
	EE0	Swaraj-India	1	**2**	**2**	
OC3: Tractors Medium to large scale maize & tobacco on loamy soils (50-65Hp)	MM0	Valtra- Finland	2	**3**	2	MF-Pakistan has been on the market for only five years. MF-Brazil and older versions, MF-UK have been on the market for decades and they are still in use.
	MM1	MF- Brazil	1	1	**3**	
	EE1	MF- Pakistan	**3**	2	1	
	EE0	_				
OC4: Tractors Upland sugar and rice on clay (All farm sizes) (65Hp+)	MM0	New Holland-EU	**3**	**3**	2	Brand loyalty of farmers, stock of MF-UK in the system already and the user experience/capability could be driving the diffusion pattern
	MM1	MF- Brazil	1	2	**3**	
	EE1	Farmtrac 60- India	2	1	1	
	EE0	_	.	.	.	
OC5:Tractors Irrigated sugarcane and rice on clay (All sizes) (65Hp+)	MM0	New Holland-EU	2	**4**	3	Low acquisition cost of machine & their availability on the market maybe influencing this diffusion pattern. Though the Chinese tractors are low cost the spare parts are difficult to find.
	MM1	New Holland-Turkey	**4**	2	2	
	EE1	New Holland- India	3	3	**4**	
	EE0	YTO- China	1	1	1	

****Rank 4 is Best and Rank 1 is Least Best; BCR- Benefit-Cost Ratio**

Source: Author's computation, 2012/2013

The dominance of Massey Ferguson (Brazil) under OC4 does not stem from economic profitability or higher capacity utilisation. New Holland (EU) is the most profitable technology under OC4 and uses the highest level of its capacity. The same tractor (New Holland (EU)) is however second to Massey Ferguson when it comes to level of diffusion. The long-standing brand loyalty that farmers have for Massey Ferguson and the capability built by users over the years for its management and maintenance is key. Finally, under OC5, the dynamics of profitability and diffusion are also not correlated. The highly profitable New Holland (Turkey) is number two from the bottom in terms of diffusion. The second most profitable technology (New Holland-India) happens to be the most widely diffused under OC5. Whilst New Holland (EU) uses the most capacity compared to the rest, the Chinese YTO performs poorly under all three measures. YTO is the least profitable, has the lowest capacity utilization and is also the least diffused (See Table 8.6). The relatively lower acquisition cost of the Indian New Holland, compared with the Turkish New Holland, could be the driver of this diffusion pattern.

8.2.3 Explaining profit and diffusion convergence or divergence

At the small scale level, power tillers with higher profitability tend to diffuse more. One would have however expected that with the notoriously high levels of breakdown of EE_0 power tillers, even if they were profitable, users would show little interest. It is however worth noting here that spare parts for EE_0 power tillers are cheaper and easily obtained in most villages where they are used. Therefore its repar is relatively easy. The fact that they are also capital efficient means that the strain on household consumption during the initial purchase is also lower. Thus for new users in Pawaga and Magugu who have not experienced any other power tillers apart from Amec, they are very happy with it. However, for second and third time buyers who have accumulated some resources over the period, and have also seen other people use MM_0 and MM_1 machines, their tastes and preferences have shifted upward for higher quality machines. Some of the farmers in this second group of users desire to move up the quality scale, but the supply of the MM power tillers and spare parts are limited on the market.

For example some farmers in the study sample had cash in hand for close to two years with the hope of purchasing Siam Kubota power tillers. They have made several telephone calls and trips to distributors in search of the machines without success. This market constraint was confirmed when, at a national exhibition, a salesman for the main importer of Siam Kubota informed me that the power tiller on display had already been bought by a farmer three months ago and they had asked him to bring it around for exhibition because they had no stocks left in stores. The supply side story is also important in explaining this diffusion pattern where EE_0 machines have an upper hand. There are many sellers of EE_0 power tillers and the quantities available on the market at any one point in time are very high. Perhaps, if there were a balanced supply level of MM_1 and EE_0 power tillers on the market, we might have observed an increasingly balanced diffusion pattern, as farmers accumulate capital over time.

The groups of tractors in use by OC2 farmers are mainly Farmtrac-45 and Swaraj. There are however pockets of historical brands like Fiat and Massey Fergusson (UK). There is no active market for these historical brands currently because it might be that Farmtrac-45 and Swaraj are serving the needs of users well or perhaps they are not available when needed. While the profitability analyses suggest that Farmtrac-45 should lead the way, in terms of diffusion, this has not happened. Many users attest to the fact that Farmtrac-45 is more stable and produces more power when in use than Swaraj. Yet diffusion of Farmtrac-45 has not been greater than Swaraj. Frequent breakdown is an important drawback for Farmtrac-45. There are major problems with the gear box. The carbon steel with which the gears are made is not hardened enough, and so the teeth are lost frequently, resulting in oil leakages and constant need for servicing. This can be time wasting and not good for a business which relies heavily on timeliness of operation.

Subsidies[38] made Farmtrac-45 market prices lower. As a result we assume a number of users had bought them mainly because of the lower price and not the value it can contribute to the farm business. Aside from these challenges, spare parts[39] are very difficult to come by. Swaraj on the other hand does not break down often, and spare parts supply is not a challenge. And as one user put it, when buying a tractor you must look for one which gives you peace of mind; to him Swaraj does this better than the Farmtrac-45. He however mentioned that an improvement in the gear box capacity of Swaraj to match the engine size would be welcomed. The broad inference that can be drawn here is that when government does business it may not do it as well as private sector. For instance, other private businessmen argued that the non-existent of spare parts for Farmtrac is because the staff at Suma-JKT will be paid whether they make sales or not. But for the private business which is aware that salaries are directly paid from revenues, there is no way they will look on as their investment goes bad.

Brand loyalty and brand reliability, as well as knowledge and skill development through time by users of Massy Ferguson (MM_1) has meant that under any condition in which they are used in Tanzania, they tend to have a higher level of diffusion than others. Users agreed that Massey Ferguson was easy to operate and the spare parts are always available compared with other competing brands. Therefore even many years after the last production from its plant in Coventry, UK, users are happy to use them whether they are produced in the USA or Brazil. Since the termination of production of medium sized versions from the USA plants in 2008, it has meant that the next most reliable source is Brazil. Even though it is the least profitable tractor under OC4, Massey Ferguson (Brazil) leads the penetration levels. The total change of name from the time when Ford and Fiat were combined to create the New Holland might have also confused some farmers, to

[38] Under the Suma-JKT distribution scheme, public opinion and pressure forced the government to reduce prices to a level that farmers could afford.
[39] During two separate key informant interviewers, spare parts sellers thought I might know why the spare parts supply for Farmtrac in general was not meeting demand.

the extent that the demand for New Holland is not as high as demand for Ford and Fiat where in the 1980s and early 1990s.

Until recently, not many farmers knew that it was their favourite Ford and Fiat technologies which had been combined to produce the New Holland they see around. Therefore the excellent performance by New Holland (EU) in terms of the BCA, has not translated into high levels of penetration. It is worth noting that the main supplier of New Holland in Tanzania (Hughes Motors) folded at some point and then re-entered the market not too long ago. There is a likelihood that this break might have also militated against diffusion. Nonetheless, the presence of New Holland is being felt again, mainly because of its reliability. Challenges faced by Farmtrac-60 under OC4 are similar to those discussed for Farmtrac-45 under OC3. However in addition, the fuel inefficiency of Farmtrac-60 also makes some farmers disinterested. They argued that Farmtrac 70 for instance had a Perkins engine from UK and was more fuel efficient than lower horsepower ranges of the same brand made with Indian-based engine technology. It may also be correct to say that with the recent pace of diffusion for Farmtrac 60 since 2010, if it continues this way, we will see their sales overtaking Massey Ferguson (Brazil) very quickly.

The story does not change significantly for OC5. Neither of those machines with the highest BCR nor capacity utilization were the most diffused. New Holland (Turkey) is the most profitable tractor whilst New Holland (EU) has the highest capacity utilization. There is however a mismatch between these findings and the fact that New Holland (India) is the most diffused. In terms of quality, the Indian versions of New Holland are probably at the bottom. Two main factors are likely drivers of the diffusion patterns observed. First, is the fact that the Indian New Holland is 'good enough' for the rather difficult terrains of irrigated clay fields and also comes at a relatively affordable price, making it the most capital efficient after the Chinese YTO. Second, government participation in its imports has increased supply and with an already existing open market, the spare parts challenges faced by Farmtrac are generally overcome. The fact that spare parts for the EU or Turkish New Holland tractors can be used for the Indian machines ensures that the supply side challenges are minimised. YTO could have appealed to users much more if the spare parts market was reliable. Often when breakdowns occur, accessing spares for YTO is a daunting task mainly because of the importation monopoly held by the company, AFRICATIC Ltd, Tanzania. Having discussed the factors influencing diffusion patterns, in the next sub-section we examine the impact of choice of technique (techniques so diffused) on low income groups.

8.3 Financing

As we shall see in the following sub-sections, farmers either use savings from their own production, pool resources with other farmers, or borrow money from financial institutions to buy tractors and power tillers. The first two options as a source of finance present challenges especially to low income farmers. For instance because farm profits are also used for household consumption, they are rarely available to finance machinery purchases. There are also management difficulties when farmers pool resources to jointly procure and use power tillers or tractors. Thus a more reliable source of financing machinery procurement is borrowing. We discuss these sources in turn.

8.3.1 Farm profits and savings

For low income groups, the first and most important step to growth is access to the inputs which enhances productivity. The obvious barrier to peasants in accessing capital goods, as mentioned several times in this study is finance. The financial barrier tends to vary across farms. In general smaller sized farms are more capital constrained compared to larger ones.

As an identification of the financial position of small, medium and large scale farms in terms of profits available for machine purchases, Table 8.3 computes farm surpluses[40] for each of the four crops under consideration. Based on average gross margins and associated costs for maize (Burke, Hichaambwa, Banda, & Jayne, 2011), rice (RLDC, 2009) sugarcane (Field Data, 2012) and tobacco (Kuboja & Temu, 2013), average farm profits are generated for each of the three groups of farms: small (4.5 acres), medium (19.5 acres) and large (70 acres). Using data from the 2007 Household Budget Survey, annual consumption by average households for the five poverty quintiles[41] are also computed (Mkenda, Luvanda, & Ruhinduka, 2009).

Subtracting average household consumption from net farm profits gives the surpluses available for investment. Households with smaller farms are more likely to consume a higher proportion of their output than larger farms. This leaves little savings for investment. Aside from sugarcane growing households, where the proportion of small and medium scale farms to large scale farms is 50%, farmers cultivating maize, rice and tobacco are dominated by smallholders. Small scale farms represent more than 80% in each of the crop sub-groupings of farmers. Therefore household savings are critically low, assuming farming is the main source of income.

Table 8.8 clearly shows that profits accruing to farming households are progressive with farm size for each particular crop. Across crops however, tobacco outperforms the others in all instances, regardless of the farm sizes. It is also evident that the least profitable among the four crops is maize. This places maize producers a step below other farmers in terms of saving for investment in capital goods. Our attention must be drawn to the fact that maize is a very important food security crop in Tanzania, aside being produced by the highest proportion of farmers in the country. Thus in a broader perspective, it is

[40] This represents the savings made by the farm household after cost of production and household consumption are catered for.
[41] To allow for simplicity of the analyses, the first and second and the fourth and fifth quintiles are combined

more likely that cash crops like tobacco which is not very important to the majority of the poor and cultivated by fewer and richer households (about 80,000) would have enough resources to invest in capital goods. At the same time maize producers have limited financial resources accruing to them as surpluses for investment. The profitability of rice is second to tobacco, but the quantity of rice produced per annum in Tanzania is a fifth in value terms when compared with maize.

Table 8.8: Farm size, crops, national output, household wealth and savings from farming

	Food crops		Cash crops	
	Maize	Rice	Sugarcane	Tobacco
Cultivated area and output in Tanzania				
Area cultivated (millions of Ha)	1.5	0.7	0.05	0.1
Output (millions of metric tons)	4.5	1.1	2.9	0.09
Current supply gap (%)	5	10	42	_
Proportion of farms by size (%) in Tanzania				
Small (<9 acres)	85	90	25	95
Medium (10 to 39 acres)	10	8	25	3
Large (>40 acres)	5	2	50	2
Farm profit per acre (TSH '000,000)	0.2	0.9	0.6	1.1
Small (<9 acres)	0.9	4.1	2.9	4.9
Medium (10 to 39 acres)	4.1	17.7	12.6	21.1
Large (>40 acres)	14.6	63.6	45.1	75.9
Household sizes				
Quintile 1 and 2	5.9	5.9	5.9	5.9
Quintile 3	5.0	5.0	5.0	5.0
Quintile 4 and 5	3.7	3.7	3.7	3.7
Household consumption (TSH 000,000)				
Quintile 1 and 2	0.4	0.4	0.4	0.4
Quintile 3	0.6	0.6	0.6	0.6
Quintile 4 and 5	0.9	0.9	0.9	0.9
Net farm profit less consumption (TSH '000,000)				
Small (<9 acres)	0.7	3.7	2.5	4.5
Medium (10 to 39 acres)	3.5	17.2	12.0	20.6
Large (>40 acres)	13.7	62.7	44.2	74.9

Source: Authors computation, 2013

Besides the fact that sugarcane is over three times more profitable than maize, the dominance of medium and large scale farms also gives sugarcane producers a greater impetus when it comes to capital accumulation for investment. Larger farms also provide a greater scope for full capacity utilization. In addition, a greater proportion of sugarcane farmers are in an out-grower scheme. The nucleus farms responsible for the establishment of these schemes sometimes assist sugarcane farmers when it comes to machine purchases through loans guaranteed by expected farm produce. Consequently different producers face different levels of financial constraints, and more acute for small scale farmers producing mainly food crops, like maize.

For some households, it is unrealistic to assume that they can save over any specified number of years to buy a tractor, for example if the household cultivates just an acre of land. Under the present assumptions, they may borrow to smooth their seasonal consumption budget lines if there are unexpected income shocks. They are in deficit and cannot set money aside to buy a tractor. Small scale maize farmers cultivating one acre are in a deficit of about TSH160,000 per annum, and there is no room to save. For others like large scale tobacco farmers, a year's profit is enough to buy them several power tillers or tractors.

One way of measuring how difficult it is for various farmers to access different categories of tillage technologies is the number of years it will take them to save and raise enough money for the purchase. In Table 8.8 therefore estimation is made of savings period necessary for the average farmer to raise money for a particular machine under their OC. Generally for all OCs, farmers cultivating an acre of land per year are not likely to ever raise enough money during their lifetime to buy a power tiller or tractor. It is however possible for a number of farmers to come together and combine resources to buy a single machine to be used by all members. Clearly because of the need for timeliness of farm work and the fact that power tillers and tractors are indivisible, the smaller the group, the better. Tractor and power tiller categories that can better support these resource pooling strategies with the time constraint of land preparation in mind are EE ones. Though resource pooling strategies and use of own farm profits are possible alternatives for buying machines, the challenges involved in managing such groups makes it unattractive. A more viable way is for individual farmers to use bank loans, a point we shall return to later.

Similar arguments can be made for the other OCs. For OC2, profits for very small maize farms are so low that coming together to buy a tractor of any size by a group of famers will be a difficult thing to do. Thus one way of getting around this problem is to hire equipment when it is needed. But as we saw throughout our discussions in earlier chapters, under OC2, there are very few MM machines on offer for hiring by rural entrepreneurs. Formerly, there were smaller horsepower versions of Massey Ferguson, International Harvester and Fiat (mainly second hand from the EU and sometimes Poland) for farmers to hire. However, with farms in Europe becoming larger in size, these options are becoming limited.

Present day tractors like New Holland (EU, Turkey or Brazil) are all usually above 50Hp. Using tractors which have a horsepower higher than 50 on mainly sandy soils can be inefficient. This inefficiency stems from the fact that the excess horsepower could have been used on other fields where it is needed most. The other alternative would have been to buy Kubota tractors from Japan. Kubota has a wide range of horsepower which can be fit for purpose under OC2. The prices of brand new Kubota are however extremely high and second-hand versions are non-existent for the Tanzanian farmer. Thus the alternatives left are the EE_1 and EE_0.

Persistent across farm sizes under OC2 is the fact that it takes approximately 30% more time for farmers to save and buy an EE_0 than to buy an EE_1 machine. Thus in terms of how quickly OC2 farmers can save and buy a machine, EE_1 gives them a greater advantage. But the fact that EE_1 machines are bedevilled with a poor spare parts market makes them unattractive.

The average medium-sized maize farmers wanting to buy an MM tractor for their operations will take close to two decades to save and realize this dream. If they wished for an EE machine it will take a less than a decade. As we saw earlier, the BCA measure of profitability under OC3 suggests that EE_1 (Massey Ferguson- Pakistan) machines are the most profitable. Thus it may be an unnecessary waiting time to buy a Finish Valtra or a Brazilian Massey Ferguson, when Massey Ferguson (Pakistan) can be obtained within a shorter time of savings or by a fewer number of farmers coming together. On the other side of the coin, tobacco producers under OC3 can go for machines from either source. They have the resources and it takes a little over 3 years for medium-sized farmers to buy an MM_1 tractor. However, within the same period, they could have also obtained 3 machines from EE_1 and perhaps created more jobs in the value chain.

The story is consistent under OC4 and OC5. For farms operating on 1 to 3 acre plots, it is difficult to buy their own machines, except through selling of assets or other financial arrangements. They will have to settle for hiring and if the differences in prices charged by MM and EE machines is anything to go by, then we expect small farmers who are capital constrained to be more interested in EE machines. Rice farmers can generally save faster and buy tractors more easily than their sugarcane counterparts. If it takes 2 years of savings for a rice farmer under OC4 and OC5 to buy a tractor, it will take a sugarcane farmer 3 years. Across categories of technologies, EE_0 users take approximately a third of the time taken by MM_0 users to save and buy their tractor under OC4 and OC5. See Table 8.9.

These findings certainly have implications for policy, especially when it comes to government assistance. Fundamental questions being raised include which farmers are vulnerable and thus deserve assistance and what are the likely outcomes for such interventions? In the next sub-section, discussions on debt financing of capital goods is discussed with a view of knowing how many machines can be purchased with all the loans available vis-a-viz the source chosen.

Table 8.9: Operating conditions and number of years required to save by small, medium and large scale farmers for the purposes of purchasing the different technologies

		Farm size/savings period (years)		
	Technology	small	medium	Large
	MM0	4.3	0.9	
	MM1	3.5	0.8	
OC1	EE1	2.2	0.5	
Rice	EE0	1.6	0.3	
	MM0			
	MM1			
OC2	EE1	31.8	5.2	1.3
Maize	EE0	42.3	6.9	1.8
	MM0		18.6	4.8
	MM1		19.5	5.0
OC3	EE1		7.4	1.9
Maize	EE0			
	MM0		3.2	0.9
	MM1		3.3	0.9
OC3	EE1		1.3	0.3
Tobacco	EE0			
	MM0	18.8	4.1	1.1
	MM1	18.3	4.0	1.1
OC4	EE1	6.7	1.5	0.4
Rice	EE0			
	MM0	27.7	5.8	1.6
	MM1	26.9	5.7	1.5
OC4	EE1	9.9	2.1	0.6
Sugarcane	EE0			
	MM0	18.8	4.1	1.1
	MM1	14.8	3.2	0.9
OC5	EE1	12.4	2.7	0.7
Rice	EE0	6.5	1.4	0.4
	MM0	27.7	5.8	1.6
	MM1	21.8	4.6	1.2
OC5	EE1	18.2	3.8	1.0
Sugarcane	EE0	9.5	2.0	0.5

Source: Author's computation, 2013

8.3.2 Commercial Bank loans and Agricultural Input Trust Fund

As demonstrated in the discussions in Section 8.3.1, saving to buy a machine can sometimes be challenging for small scale farmers. Again group formation that attempts to pool resources also has its own challenges. Thus a more viable approach is for the farmer to borrow to finance investment. This section looks at the opportunities available to the farmer by financial institutions in Tanzania.

Commercial bank loans that go to agriculture per annum are between 10% and 15% of the total for all sectors in the Tanzanian economy. In 2011 when total commercial bank lending stood at TZS7.6 trillion, at least TZS1.15 trillion went to the agricultural sector. This was to finance investment in land, irrigation and irrigation infrastructure, labour, seeds, agrochemicals, processing, marketing, draft power, implements and farm machinery. If we assume that farmers allocate 90%[42] of these loans to all other inputs except mechanical tillage equipment, then about TZS115 billion will be available for the procurement of power tillers and tractors. Let us assume for the sake of our discussion that this allocation to farm machinery can be spent only on the five operating conditions in this study and each operating condition is entitled to a fifth of the total amount. Then by simple proportion computations, all producers in each of the OCs have access to TZS23 billion to invest in MM or EE power tillers or tractors suitable for their operating purposes. Table 8.10 gives a breakdown of the number of power tillers and tractors from MM or EE sources that can be bought with these loan allocations.

From the last two columns of Table 8.10, it is clear that with the same amount of money, all small scale farmers cultivating rice under OC1 can purchase twice as many power tillers from EE than if they chose to do so from MM sources. Farmers under OC2 to OC5 can acquire four times as many tractors from EE sources than they would from MM sources. These proportions have implications on income, employment and skill

[42] For example in the United States about 8.3 percent of farm expenditures went to farm machinery and other mechanical power in 2012 (USDA- National Agricultural Statistics Service, 2013).

development of value chain participants. We shall discuss these in turn later in this section.

Table 8.10: Financing MM and EE procurement with a fixed annual loan from banks

	Tech	Total farm loans TZS (Trillions)	Loans per Tech TZS (Billions)	Tech cost TZS (Millions)	Potential purchases (count)
OC1 RICE	MM0	1.15	23	16	1438
	MM1			13	1769
	EE1			8	2875
	EE0			6	3833
OC2 MAIZE	MM0		23		
	MM1				
	EE1			18	1278
	EE0			24	958
OC3 MAIZE	MM0		11.5	65	354
	MM1			68	338
	EE1			26	885
	EE0**				
OC3 TABACCO	MM0		11.5	65	177
	MM1			68	169
	EE1			26	885
	EE0**				
OC4 RICE	MM0		11.5	70	165
	MM1			68	169
	EE1			25	920
	EE0**				
OC4 SUGAR	MM0		11.5	70	165
	MM1			68	169
	EE1			25	920
	EE0**				
OC5 RICE	MM0		11.5	70	165
	MM1			55	209
	EE1			46	250
	EE0			24	479
OC5 SUGAR	MM0		11.5	70	165
	MM1			55	209
	EE1			46	250
	EE0			24	479

**Loan allocation for cells without brands have been added to their closest match for the computations

Source: Author's computation, 2013

In addition to bank loans, the Agricultural Input Trust Fund of Tanzania also sets aside some money for farm machinery purchases. Whilst AITF does not decide for farmers the kind of machines they should buy, their grant limits indirectly influences the farmer's purchasing power, and consequently the bundle of power tillers and tractors they can afford. Any farmer applying for an AITF loan is entitled to at most (TZS37400000). With this amount, it is practically impossible for any farmer to buy an MM tractor at current prices. When the farmer adds his/her 20% down payment, the highest quality they can get are EE_1 tractors. In the case of power tillers, this figure can buy as many as six EE_0 technologies as against two MM_0 ones. If employment and distribution of growth gains is of concern to economic agents, then these dynamics are also crucial for policy and practice.

8.3.3 Impact of choice on actors in value chain

Table 8.11 to 8.15 illustrate simulations of output and value chain outcomes that are likely to be observed when farmers within the different OCs spend investment resources available to them for machinery purchases on MM_0, MM_1, EE_1 or EE_0 technologies. There are potential outcomes on the quantities of power tillers and tractors that could be purchased per year (as shown in Table 8.10) and the number of acres that can be tilled per annum. There are equally important effects on jobs created along the value chain. Under each OC, Tables 8.11 to 8.15 show how many dealers (importers of machinery) are required to manage the importation; farmers (owners) required to man the tractors for hiring or use on their own farms; operators to use the power tillers/tractors for work; and repairers to maintain them when they break down. The jobs so created, also impacts on incomes and capability development through learning by doing. In this sub-section these issues are discussed for each OC in turn.

The discussion here assumes that currently 500 power tillers and 300 tractors are imported into Tanzania annually. We further assume that the brands used for the computations under each OC are typical for each of the four classification of machine source, MM_0, MM_1, EE_1 and EE_0. Thus the acquisition costs used in the computations represent the average price of technologies within those sources. Dealers participating in these imports are 42 in number. Each power tiller or tractor employs at least one operator per time and there are on average of 4 repair shops in communities where power tillers and tractors are used. Each shop has one or two workers, usually the repairer and his apprentice or just the repairer. There can however be more workers especially for bigger repair shops in larger communities. Area cultivated by the machine is chosen as a measure of output instead of crop harvested because of the multiple factors associated with computing the partial contribution it makes in a stream of other input variables. The computations in Tables 8.11 to 8.15 are based on these assumptions.

Generally, moving down within columns of OC1, there is an increase in the number of acres that can be tilled with the machines bought given the available financial resources. Consequently, the number of people who are employed for each group of actors in the chain also increases. For instance, under OC1 spending all the farms' investment resources on EE machines will provide jobs for more than twice as many dealers than if the resources were used for MM machines. Also farmers who will own and manage power tillers under OC1 when MM_1 machines are bought are about a third of the number that will be employed if EE_0 machines were chosen. A similar observation is made for tractor drivers on farms and repair shops in each of the communities where these machines are going to be used. See Table 8.11.

Table 8.11: Choice under OC1 and employment effects

	Tech	Tillage (acres '000)	Dealers	Owners	Operators	Repairers
	MM_0	141	60	1438	1438	12
	MM_1	197	74	1769	1769	14
	EE_1	244	121	2875	2875	23
OC1 Rice	EE_0	291	161	3833	3833	31

Source: Author's computation, 2013

Under OC2, where there are only EE machines under review, Table 8.12 shows that when EE_1 machines are chosen over EE_0 there is more room for higher increases in tillage output and employment generated along the value chain. The EE_1 machines generate more than twice the output in terms of area tilled per season when compared with the EE_0. Again, a little above two-thirds of dealers required to handle the EE_1 tractors will be needed than if the technique chosen are EE_0. The number of rural enterprises that will be formed, operators employed and repairers needed are all in similar ratio in favour of the EE_1 tractors.

Table 8.12: Choice under OC2 and employment effects

	Tech	Tillage (acres '000)	Dealers	Owners	Operators	Repairers
	MM_0					
	MM_1					
OC2	EE_1	607	89	639	1278	17
MAIZE	EE_0	282	67	479	958	13

Source: Author's computation, 2013

Under OC3, the amount of money available for purchasing these technologies is shared between maize and tobacco farmers and the outcomes on the value chain are presented in Table 8.13. The area that can be cultivated under OC3 when EE_1 machines are selected is more than double the area that could be cultivated if either MM_0 or MM_1 machines are selected for both maize and tobacco farmers. Consequently, close to three times as many dealers are needed to handle the tractor imports if EE_1 versions of technologies are chosen as opposed to the MM_0 or MM_1 versions. The ratio of enterprises created as well as operators required to man the machines are well over 2:1 in favour of the EE_1 tractors. Twice as many repair shops are also likely to be created if the EE_1 machines are chosen over any of the two MM versions on maize or tobacco farms.

Table 8.13: Choice under OC3 and employment effects

	Tech	Tillage (acres '000)	Dealers	Owners	Operators	Repairers
	MM_0	92	12	89	177	3
	MM_1	88	12	85	169	3
	EE_1	210	31	221	442	6
OC3 Maize	EE_0					
	MM_0	92	12	89	177	3
	MM_1	88	12	85	169	3
OC3 Tobacco	EE_1	210	31	221	442	6
	EE_0					

Source: Author's computation, 2013

Under OC4 similar observations are made to those in OC3. EE_1 machines procured with the financial resources available to the farmer cultivate more area per season and require close to three times the number of importers needed to handle MM_0 and MM_1 machines. In a similar fashion, for every one operator that can be employed when MM machines are chosen, EE_1 will employ three. The repair shops so required also follow a similar trend. These estimations follow the same structure for both rice and sugarcane farmers under OC4. See Table 8.14.

Table 8.14: Choice of technique under OC4 and employment effects

	Tech	Tillage (acres '000)	Dealers	Owners	Operators	Repairers
	MM0	61	12	82	165	2
	MM1	47	12	85	169	2
OC4 Rice	EE1	111	32	230	460	6
	EE0					
	MM0	61	12	82	165	2
	MM1	47	12	85	169	2
OC4 Sugar Cane	EE1	111	64	230	460	6
	EE0					

Source: Author's computation, 2013

Moving down the columns (away from matured markets to emerging economies technologies) under OC5, there is a general increase in the number of acres that can be tilled per season. This in effect influences the number dealers in the value chain required for importing the machines as well as the enterprises created. Operators and repairers also increases as one moves from MM machines to EE ones. See Table 8.15.

Table 8.15: Choice of technique under OC5 and employment effects

	Tech	Tillage (acres '000)	Dealers	Owners	Operators	Repairers
	MM0	46	12	82	165	2
	MM1	54	15	105	209	3
	EE1	52	18	125	250	3
OC5 Rice	EE0	99	34	240	479	6
	MM0	46	12	82	165	2
	MM1	54	15	105	209	3
OC5	EE1	52	18	125	250	3
Sugarcane	EE0	99	34	240	479	6

Source: Author's computation, 2013

The foregoing discussions suggest that there is more opportunity to increase production through area expansion when EE machines are employed with the same amount of capital. With area expanded, more labour in the different links in the value chain are needed to fill the employment spaces created. As these participants in the value chain get the opportunity to participate in importing, managing, operating and maintaining these machines, opportunities for capability building and absorptive capacity develops. These opportunities are opened up to more people if EE machines are selected. In the next section, we discuss how fit the choice made is for purpose, their impact on environment and the health of users as rated by owners of the machines.

8.4 Fitness for purpose, environment and health issues

The best economic agent to judge the fitness for purpose of a particular technology is the user. In this case, the farmer who uses the power tillers and tractors for his production and transportation activities can judge their appropriateness. Outcomes on the environment and the effect on health and safety of users can be best judged by those who come into contact with the machine as it is being used. In this sub-section, we refer to ordinal (ranking) responses obtained from the survey data using all the respondents. The respondents were asked to rate their machines in relation to the environment in which they are used on a Likert scale of 1 to 7. Here, a response of 1 meant that the machine was inappropriate for the variable in question, a response of 7 meant that the machine was appropriate. The responses from this exercise are summarised in Figure

8.1 and 8.2 by computing the mean rank for each variable by the source of the machine (MM/EE) and the type (Power tillers/Tractors). In addition, a t-test of the mean responses are computed to find out whether the differences observed across groups are significant or merely due to chance.

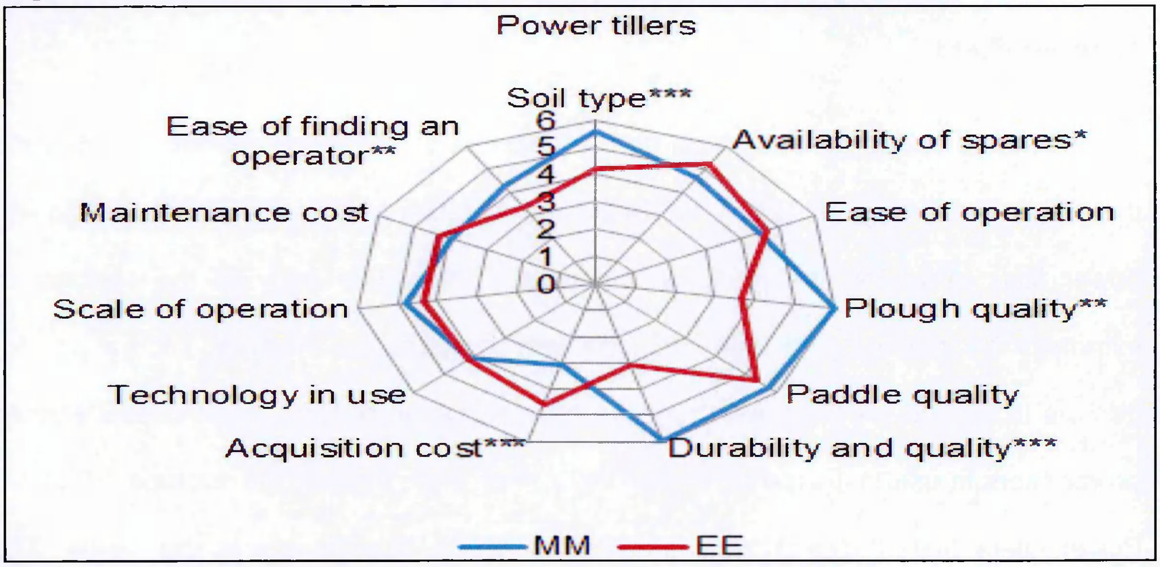
8.4.1 Fitness for purpose

a. Power tillers

In the case of power tillers appropriateness of machines in relation to the soil on which they worked was significantly different at the 1% confidence level. MM machines were rated by the users to be more appropriate than the EE ones in terms of how well it resists soil debris and works through very difficult terrains without being damaged. Consequently, the quality of ploughing was in favour of MM machines at the 5% confidence level; whilst it came as no surprise that the quality of paddling was inconclusive since EE power tillers on average come with higher horse power than MM ones, and in a way compensates for some of its inefficiencies thereof. Power tiller users of MM rated their machines very high when it came to durability and quality of machine and this was significantly different from the EE machine user ratings at the 1% level. Users also found EE machines more appropriate in terms of acquisition cost in relation to their incomes and this was significant at 1%.

A more challenging outcome which is important for policy is the fact that EE power tiller users found it more difficult to get an operator who was interested in manning their machines for them and this was significant at the 5% confidence level. Because of the frequent breakdown of EE machines, operators shy away from them. Some operators are also uncomfortable with the relatively high weight of EE machines which puts a lot of stress on their muscles. Spare parts availability for EE power tillers is rated by users to be more of an issue than for the MM machines at 10% significance level. See Figure 8.1.

Figure 8.1: User satisfaction, power tillers (ranks on a scale of 1 to 7)



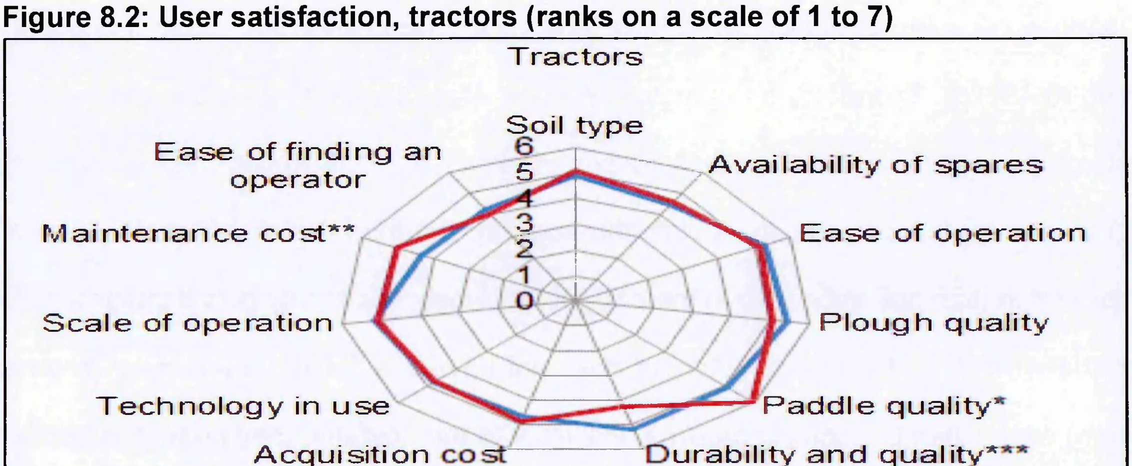
Significance level: 1% ***, 5% **, 10% *

Source: Field work, 2012/2013

b. Tractors

At the 10% confidence level, user rating of EE tractor performance during paddling was better than the MM ones. However, users of MM tractors found it to be of higher quality and durability than their EE counterparts at the 1% confidence level. The cost of maintaining tractors were however significantly different for the two sources and in favour of EE users. See Figure 8.2.

Figure 8.2: User satisfaction, tractors (ranks on a scale of 1 to 7)



Significance level: 1% ***, 5% **, 10% *

Source: Field work, 2012/2013

8.4.2 Health, safety and environment

a. Power tillers

Manufacturers of Kubota, and obviously Siam Kubota have through research established that beyond the range of 12HP and 14HP, the vibration and the force that the moving power tiller exerts on the muscles and indeed the whole body of the operator is extremely discomforting. It thus has long term occupational hazards implications for farmers to use power tillers which are beyond this range of HP. Thus for most Kubota power tillers in use in Tanzania, the HP is 12. For Siam Kubota, the average HP is 14. Power tillers from Korea (Kukuje and Daedong) are also usually in this range. The Kubota group has however invested in innovation to ensure that the gears are efficient enough so that the pressure exerted per unit area of torque is comparable with other power tillers which may have higher horse power. The Chinese power tillers are usually of between 16Hp and 20Hp. The continual use of power tillers of high Hp and its associated high vibration is known to have short term discomfort such as body aches and headaches on the user. In the long run, both the spine and the nervous system of the user could be damaged.

From the least to the highest in terms of weight, it is in the order of Siam Kubota, Kubota, Daedong (Kukuje), Greeves, JST Shakt, and Amec (Dongfeng/Changchai/Changfa/JD) (455 to 490kg). Therefore, an operator using an Amec power tiller would require more energy to push behind it. For the purposes of rotavation, both Kubota and Amec make provisions for the operator to sit, with the addition of a third wheel and seat. However, more often than not, especially in the case of the Amec, this facility gets damaged in the first few months of use. Siam Kubota does not have this facility. Sometimes (or most often) even when the seating facility is available to the operator, they prefer to disable it and push the machine for ease of operation. In this way, the operator exposes himself to the dangers of cuts from loose metallic parts of the machine. This problem is quite common with the Amec group, where many of the parts are not tightly fitted and thus easily coming off under very little pressure from iron pan and heavy soils. The operators report that users of Amec are more likely to sustain bruises and cuts on their feet than the Siam Kubota whose parts are tightly fitted and rarely come off during usage.

Over-heating is also a serious issue both for the progress of tillage operations and the comfort of the operator (sometimes resulting in feverishness after a day's work). While very high temperatures of the engine could create a lot of discomfort for the operator, it is also very important in the work efficiency sense. That is, under very high levels of over-heated engine, the machine must be stopped for at least an hour to prevent the shafts and the engine parts from being damaged. This could take valuable time from the operator, requiring that work that could be done in say 3 hours will now be done in 4 hours. This over-heating also requires that after some specified period, the radiator water is topped up or changed completely. This is also a common fault of most of the Chinese machines. Indian ones are relatively better. Operators argue that it is very rare for them to use their Amec machines for more than 2.5 hours without having to stop it to let it cool down. For Siam Kubota users, there is no such thing as resting the machine while in use. For their 8 hour day job, they only stop the machine when they are tired themselves. All they need to do is to follow the manufacturer's routine maintenance instructions.

Other pollutants such as incompletely combusted fuel in the form of smoke, oil leakages and noise levels are also to varying degrees a cause for concern for both the user and the environment. Amec is quite noisy and irritating to the ear. What one cannot say from this research is whether these noise levels are at a threshold that can damage the ear drum of the user. By contrast, Siam Kubota is not very noisy, but then again the acceptable levels of noise decibels may be controversial. However, in relative terms, the Amec engine is more likely to create hearing impairment for the user over time than the Siam Kubota.

For either of the two machines (Amec and Siame Kubota) of the same age, smoke and oil leakage levels from the Amec is higher. The smoke does not only create discomfort for the eyes of the user, but also contributes to the greenhouse gas accumulation in the long run.

While the release into the soil of leaking grease and machine oils onto the rice fields may be minimal in the short run, long term accumulation may be of concern. In as far as scrap metals is concerned, for every kg that Japanese Siam Kubota assembled in Thailand releases into the Tanzanian environment, the Chinese Amec releases 3.5kg, that is to say for every one purchase a user makes of Siam Kubota, another user buying an Amec must purchase at least three to make up for the life span of the Siam Kubota. To add to this discussion, one may also draw on how often the user must replace Amec spare parts. Evidence from a focus group with women users of the two groups of machines in the *Mabadaga* village suggests that in the cultivation season of 60 days per year, the users of Amec are likely to visit the spare parts shops as many as 18 times compared with 2 or 3 times by their Siam Kubota/Kubota counterparts.

b. Tractors

Across the two groups of tractors, none of the environmental measures were assessed to be different from the other. However, EE tractors vibrated more and generated more noise than the MM ones. Because most of the MM tractors were older, they also generated more smoke than the EE ones. In terms of release of exhaust smoke, since some EE machines consume more fuel per acre, there is the likelihood that in general their combined effect of total smoke released into the atmosphere could be higher. See Table 8.16 below.

Table 8.16: Pollution and ergonomic Indicators

Scale of Technology	Indicator	Source and farmer rating [a] MM	EE	p-value
1. Power Tillers	Vibration	3.06	4.13	
	Noise	2.89	4.27	***
	Smoke	2.47	4.00	
2. Tractors	Vibration	2.78	3.02	
	Noise	3.68	3.23	
	Smoke	3.97	3.22	

[a] 1-lowest; 2-very low; 3-low; 4-neutral; 5-high; 6-very high; 7-highest
Significance level: 1% ***, 5% **, 10% *

Source: Field work, 2012/2013

8.5 Conclusion

This chapter has shown that a direct relationship between physical coefficients, profitability and diffusion is complex. It is however evident that the technologies which are likely to be diffused depends mostly on the incomes of farmers and their access to finance. The availability of the machines and their spare parts upon demand is also crucial. Thus in a predominantly smallholder environment where farm profits are low, demand for tillage equipment is dictated by how much savings the household can make. There are also limited opportunities from commercial banks for capital goods investment financing. With expanded output, employment, and capability building at the forefront of national policy, a choice of technique that gives as many people the opportunity to participate in the input market, production process and services associated with the agricultural sector is important. Computations about possibilities in terms of output, income and employment increases that are likely to unfold when EE machines are chosen over MM are also key. However, the broad outcomes are clear- most national and farm level objectives can be reached twice as fast if EE machines are chosen over MM ones. The challenge is how to remove bottlenecks like unreliable spare parts supply especially in the case of tractors and in the case of EE power tillers and tractors, the unavailability of operators who are willing to staff such machines.

Chapter 9 : Summary, Conclusion and Implications for Policy

9.1 Introduction

This thesis examined the distinctive nature of tillage technologies from different sources outside Tanzania: mainly Matured Markets (MM) and Emerging Economies (EE). To do this, four research questions were defined related to the following issues: mode of transfer of technologies; penetration level and extent of use of the technologies; distinctive features of technologies; and how pro-poor the technologies are. In this Chapter, we present the findings of the study and discuss the implications they have on theory and policy. First the general findings about the nature of the sources, scale and users of technologies are presented. This is followed by a brief discussion of the roles each actor play and the gaps that exist between what is expected of an actor and what they are currently able to do within the chain of technology transfer. Detailed findings per each research question are then presented including a clear and precise answer to each question. The implications for theory and policy are then analysed. After some directions for future research are given, a brief conclusion is made.

9.2 Brief summary

Growth in Tanzania has resulted in disproportionate gains to different sections of the population (Chapter 1). Tanzania is a relatively poor country dominated by smallholder farmers operating under resource constrained conditions. The industrial sector is unable to produce mechanical tillage technologies locally and the country must import them from abroad (Chapter 2). The importance of mechanical technologies on farms in promoting growth is well recognised and there is a choice to be made from advanced country and emerging economy technologies. The effectiveness of this choice will have significant ramifications for poor producers. The rise of China and India in the development and generation of technologies could be a game changer in the choice environment (Chapter 3). To understand how this choice is made and the outcome of the choice, an empirical study targeting importers, financial institutions, repairers, regulators and users is required. Economically more profitable technologies are likely to diffuse, and so an estimation of this profitability is also needed (Chapter 4).

There are four emerging and distinct sources of technologies being used by small/medium/large scale rice, maize, sugarcane and tobacco farms in Tanzania. Their farms are either irrigated or rain-fed and they employ either small machines (power tillers) or large machines (tractors) (Chapter 5). The main modes of transferring technologies into Tanzania are through trade, FDI, aid and licensing. In the past, the main sources from which technologies were transferred to Tanzania were the EU, USA and Japan. Presently, more tillage technologies are imported from China, India and Pakistan. The advanced country machines are pre-dominantly engaged in cash crop production whiles those engaged in food crops are from emerging economies (Chapter 6).

The advanced country machines are high quality and come at a higher cost compared with the emerging economy ones. Availability of spare parts is an issue for emerging economy tractors whilst, advanced country power tillers are also bedevilled with the same problem. Small machines are generally more profitable than large ones. Most large machines, regardless of their source do not break-even in terms of profitability. However emerging economy tractors are generally less profitable than their advanced country counterparts (Chapter 7). That said, emerging economy machines are more pro-poor because they are used mainly by food crop producers. Because of their low cost, emerging economy machines reduce the entry barriers for users in terms of cost and the time required to save towards their purchase. Emerging economy machines are however less friendly to the environment and users by releasing more fumes, noise and vibration during usage. However, they create more room for employment per unit of output and for a fixed amount of capital more users can have access and cultivate a greater land area when compared with matured market ones (Chapter 8). In the next two sub-sections we present some general findings of the study.

9.2.1 Scale, sources, categories and users

The study found that there were two broad scales of mechanical tillage technologies being used in Tanzania: power tillers and tractors. Power tillers are two-wheeled walk behind machines with horsepower between 12 and 24. Within power tillers, there are two kinds: those whose implements are propelled by the engine through a drawbar and those propelled by the motion of the machine. Tractors usually come with a horsepower of 25 and above. Based on the wheel system there are three kinds of tractors: 2WD, FWA and 4WD.

Power tillers and tractors are imported from two main sources: Matured Markets (MM) and Emerging Economies (EE). Major economies participating in the MM sources are EU, Japan and USA. India, China and Pakistan are the major EE countries supplying tractors and power tillers to Tanzania. Some of the power tillers and tractors are also imported from Thailand, Brazil, Turkey and South Korea. The Turkish and Brazilian companies are mainly subsidiaries of businesses in the USA or Europe or sometimes operating under license. From these two main sources, MM and EE, four broad categories of technologies were classified: MM made in the North (MM_0); MM made in the south (MM_1); MM adapted to EE made in the south (EE_1); and EE made in the south (EE_0). Altogether, there were close to 38 brands of tractors and power tillers on the Tanzanian market. These machines were used under different operating conditions characterised and summarised in Table 9.1 based on discussions in section 5.6.

Table 9.1: Characteristics of operating conditions

OCs	Farm size	Crops	System	Hp.
OC1	Small	Rice on clay soils	Irrigated	up to 24
OC2	Small, Medium, Large	Maize intercropped with pulses sandy soils	Rain-fed	25 to 49
OC3	Medium, Large	Maize and Tobacco intercropped with vegetables loamy soils	Rain-fed	50 to 75
OC4	Small, Medium, Large	Rice and Sugarcane clay soils	Rain-fed	60 and above
OC5	Small, Medium, Large	Rice and Sugarcane clay soils	Irrigated	60 and above

Source: Based on discussions in Section 5.6

9.2.2 Role of actors and institutions

In Chapter 4, we showed that different actors within the power tiller and tractor markets in Tanzania have different roles. These actors consisted of government institutions, manufacturers, dealers, financial institutions, repairers and users/user groups. Government, government institutions and donors which tend to act as a referee, govern or support the market in an attempt to control imperfections. Aside from government all other actors are primarily driven by the Schumpeterian motor of profit maximisation. Once equipped with information on farmer needs, agents within the power tiller and tractor value chain are set for the importation, distribution and maintenance of tillage technologies with the view of making profit. To achieve this goal requires that the challenges presented within the market must be minimised while satisfying the needs of the final consumer.

Government's role as a regulator and as a facilitator has been pervasive. Government engages in the setting up of trade rules such as subsidies and taxes. It also provides extension services through the Ministry of Agriculture and Cooperatives to users. The formal institutions responsible for training operators and mechanics are also run by government. Quality testing and assurance are all maintained by the institutions set up by government. More recently, research and design of tractor prototypes have also been undertaken by government institutions, with field trials being carried out presently. One key gap between what governments ought to do and what it is able to do include the fact that testing rules which are supposed to ensure that the right standards of machinery are imported into the country are not strictly enforced. In cases when they are applied, test results are not published for the benefit of prospective buyers.

Manufacturers on the world market produce mostly for their own countries and export a few tractors to other countries. For instance only about 5% of all the tractors produced in India are exported. However some manufacturers including M&M have recently opened outlets in Tanzania with the view of studying the East African market for further expansion. The same company has signalled its intentions of starting an assembly plant soon.

Critically, spare parts supply for MM power tillers and some EE tractors are major challenges within the market that can be attributed to manufacturers and their rules of engagement with importers. The very low quality of spare parts, especially for EE power tillers and tractors is also a problem.

In all, there are 42 dealers engaged in the importation and distribution of agricultural machinery in Tanzania. They are mostly concentrated in Dar es Salaam but have affiliates and networks across the country. The MM dealers have a very long history in the country, whilst the EE ones are relatively newer but are growing quite rapidly. Some of the dealers have taken advantage of the subsidies given by government on tractors and power tillers to import the farm machinery. However, because the subsidies do not cover the flow of spare parts needed to cover the entire lifespan of the machines, some dealers only sell the tractors and refuse to import the needed spare parts. This creates shortage of spare parts, and the few dealers who import them therefore charge very high prices.

The main forms of finance for buying farm machinery include personal savings of farmers, resources from co-operative groups, government trust funds and commercial banks. Commercial Banks are the most popular sources of financing machinery purchases. The average interest rate for buying agricultural machinery ranges from 8 to 20% depending on the source. There is evidence from the survey that more users of MM machines borrow money to buy their machines than EE users. Commercial Banks only lend money to farmers who have a minimum acreage of 10 acres when they want to buy power tillers or 40 acres for those wanting to buy tractors. This criterion excludes a lot of farmers from being able to own a tractor or power tiller. There is also a down-payment of 20% to be made and this adds to the challenges faced by prospective buyers. What is quite worrying is that this criterion is across the board whether the machine is of MM or EE origin, without taking cognisance of the fact that EE machines are generally lower cost.

The users of tractors and power tillers are small, medium and large scale farmers. The small scale farmers usually have food security objectives, and then sell the surplus. The medium and large scale farmers have greater market orientation.

Repairers deal directly with the owners and their operators and provide a critical service to keep the machines running. About 65% of incomes obtained by repairers per annum come from the service they provide to EE machine owners. There is a higher tendency for more experienced power tiller operators to be attracted to MM machines than EE ones. This makes the already fragile EE machines more susceptible to damages during usage.

9.3 Originality of thesis and answers to research questions

In the past four decades, researchers in the area of technical choice concerned with appropriate technology, development and inclusive growth undertook various empirical studies to compare advanced country technologies with indigenous ones (Bhalla, 1981). They further engaged with how producers in poor countries could make an appropriate choice from these two sets of technologies (Schumacher, 1973; Emmanuel, 1982; Eckaus, 1987). General conclusions were that indigenous technologies were more often than not inefficient. Advanced country technologies were found to be efficient but because they had been developed with rich societies in mind developing country production infrastructure and market characteristics were inappropriate for developing economies. The call then was that new technologies which were medium scale, easy to operate and relied less on heavily built infrastructure should be developed and made available to poor producers in developing countries. The success stories of these initiatives by developing country governments and the donor community in general yielded minimal results, and with time the movement died down. Over the same period, a third set of technologies have evolved from emerging economies such as India and China, but has received very little attention in terms of how they compare with the advanced country and indigenous technologies, a research gap that needs attention.

In the last two to three decades capabilities and skill sets for the development and manufacture of production technologies in emerging economies, mainly China and India have seen substantial growth. Through investments in R&D, education and emphases on producing to meet the demands of a large market with a growing but smaller purchasing power compared with advanced countries, less robust but 'good enough' technologies are being made available to users in these emerging economies.

Because China and India are in themselves developing, we believe that the technologies they produce for their own production environment may hold the key to unlocking economic and social change through higher productivity levels that have been elusive in other developing countries, particularly SSA. Biggs et al., (2011) have for instance shown that Japan and Korea with all their industrial advancement have failed to develop machines that will create farm mechanisation technologies needed by developing countries in Asia. It was the Chinese industry which has created technologies that have transformed small scale agriculture in Bangladesh, India and Nepal- an experience which we believe could occur not only in SSA agriculture, but also other sectors including wood and metal working and clothing and textiles industries. There is however limited research in this area on SSA either to confirm or deny the potential that exists for Chinese and Indian technologies to contribute to increased productivity on the African continent.

The originality of this thesis therefore lies in the fact that it has uniquely compared emerging economy machines with advanced country ones to examine the hypothesis that Chinese and Indian tillage technologies could be useful to poor producers in more ways than those from the EU, Japan and the USA in SSA. Using Tanzanian agriculture as a case study, we have addressed four research questions and demonstrated that emerging economy sources of machines may not address all the tensions and needs of the farmer and his/her environment. In so far as access for low income groups is concerned they provide a stepping stone for the poor producer and other actors along the value chain to expand output, increase incomes and develop skills and competences that advanced country machines may not afford them.

Table 9.2 summarises the answers to the four research questions set out on page 8 of Chapter 1 of this thesis and the locations in this thesis where they are examined. First, on the question of mode of transfer, aid/government support, trade, and FDI/licencing are key conduits for technology imports. However, trade has been very important for EE machines whilst aid/government support has been found to be key for MM machines especially the small scale ones. Second, in terms of penetration and extent of use, EE machines are more popular when it comes to small scale power tillers than MM ones. However the total stock of MM tractors is known to be greater than EE ones though we are recently witnessing EE tractor numbers increasing more rapidly than MM ones. Third, MM machines are generally superior in terms of engineering performance and efficiency in terms of output when compared with EE ones. Nevertheless the MM machines are capital intensive and involve higher maintenance costs because of the higher cost of spare parts and repairs. Finally, for the fourth research question we find that EE machines are more pro-poor than MM ones since they create more opportunities for employment and capability building among capital constrained users and dealers. In the following sub-sections we discuss these answers in detail.

Table 9.2: Summary of findings

Research questions	**Characteristics and features**	**Results**				**Location of results in thesis**
		Power tillers		Tractors		
		MM	EE	MM	EE	
1. What is the mode of transfer and diffusion of MM and EE tillage technologies in Tanzania?	Aid/government support	Important	Important	Important in the past	Important	Chapter 6, Section 6.2. Sub-section 6.2.1 for tractors & 6.2.2 for power tillers
	Trade	Important	Very important	Important	Very important	
	FDI/Licensing	Not important	Not important	Important in the past	Not important	
2. To what extent are MM and EE tillage capital goods being used in Tanzania?	Penetration -National -Study sites	30% of all machines	70% of all machines	40-60% depending on region	About 40%, though increasing lately	Chapter 6, Section 6.5 Sub-sections 6.5.1 to 6.5.5
	Extent of use -Ploughing -Rotavation -Transportation -Power generation	Concentrates on ploughing and transportation	Concentrates on Rotavation and power generation	Concentrates on ploughing on heavy soils	Concentrates on ploughing and harrowing in lighter soils	
3. In what ways are MM tillage technologies distinctive from EE ones?	-Engineering -Economic life -Efficiency -Cost of operation -Economic optimality -Capacity utilisation	High quality and can be used for a period of 7 to 12 years. It is capital intensive, use a higher level of capacity but costs more to operate.	Relatively low quality lasting for between 2 and 4 years when properly maintained. Low cost, labour intensive, lower capacity utilisation	High quality with economic life of 10 to 12 years. Capital intensive. High cost of operation, high capacity utilisation& good output	Frequent breakdowns, lasts between 4 and 6 years. Cost of operation is high. Some overheat frequently and have a weaker gear box	Chapter 7, Sections 7.3 to 7.7

Research questions	Characteristics and features	Results				Location of results in thesis
		Power tillers		Tractors		
		MM	EE	MM	EE	
4. Do the inherent distinctive characteristics thereof, (if any), of EE tillage technologies help address the needs of resource constrained farmers and other participants in the value chain and hence reduce poverty?	Entry barriers Output Employment Skills and capability building Access to spares Access to machines Access to repairers	High entry barriers as a result of high acquisition cost. Lower levels of employment opportunity per time. Spare parts and whole machines can be difficult to find.	Lower cost barriers, employs more people per time, spare parts and whole machines are easily found. Repairers are relatively easier to find.	High acquisition and operational cost. Higher skill requirements for operation and repairs. Repairers are more difficult to find.	Lower acquisition cost, easier to find repairers. Assuming a fixed amount of capital they create more jobs per time.	Chapter 8, Section 8.3 and Section 8.4

Source: Generated by author, 2014

9.3.1 Research question 1

What is the mode of transfer and diffusion of MM and EE tillage technologies in Tanzania?

The main modes of technology transfer for both MM and EE power tillers and tractors were through aid/government support, trade and FDI/licensing. However FDI as a means of transfer is absent when considering power tillers. FDI was however important in the pre-SAP days for tractor assembling in Tanzania when the country had a production license agreement with a Finnish company. Whilst aid featured significantly in the pre-2005 wave of imports for power tillers and pre-SAP wave for tractors, the periods after 2005 and SAP has seen the importance of aid declining or being modified. When power tillers are considered, the importance of aid as a tool for importing MM machines has been very high and mainly came in from Japan through JICA. Trade features prominently for EE power tiller imports. The nature of aid for MM tractor imports is also different from the kind of aid used in importing EE tractors. Whilst MM tractor aid is mostly gifts, EE tractor aid is based on soft grants which must be paid back. Overall, the importance of trade for importing tractors and power tillers surpasses those of aid and FDI. Currently, more than 7 out of 10 tractors in Tanzania were transferred through the open market. For a detailed discussion, see Chapter 6.

9.3.2 Research question 2

To what extent are MM and EE tillage capital goods being used in Tanzania?

In 2012 the global supply of power tillers and tractors stood at 0.5 million and 1.8 million units respectively. The annual latent demand for power tillers and tractors in Tanzania were in the order of 1800 and 1500 respectively in 2011. In the same year, the actual purchases of power tillers in Tanzania were 699 units and that of tractors were 645 units. By the end of 2011, there were 4,571 power tillers and 8,466 tractors in good working condition in Tanzania. At the regional level, 25% of the power tillers were located in the

Mbeya region (see Chapter 1, 2 and 6). One out of every two power tillers in the country is located in the five regions considered in this study. The remaining 50% are spread across the other regions of the country. One quarter of all tractors in use in the country are located in the Manyera and Morogoro regions. Altogether, 44% of tractors in good working condition in Tanzania were in the five regions considered in this study. (MAFC, 2011)

Over 70% of the power tillers in use had an EE origin. Between 40 and 50% of the tractors in use were also estimated to have come from the EE and this proportion was forecasted to rise. On one of the irrigation schemes visited during the field study, 20% of the owners of power tillers were women and three out of four of these women possessed EE machines. Out of the 95 power tillers sampled across five of the 21 regions in Tanzania, 62% came from EE sources. Of the 99 tractors studied, 57% were of EE origin. Power tillers were mainly used on small scale rice fields where irrigation facilities were present. This finding attests to the fact that differences in agro-climatic conditions may mean that not all farmers benefit from a new technological innovation (Barker & Herdt, 1985). For instance maize farmers under rain-fed regimes rarely used power tillers. However, EE power tillers dominated activities like paddling (rotavation) and power generation. MM power tillers were popular when it comes to ploughing and transportation. Thus there were some complementarities between the two sources when it comes to farm work. This is not to say that each of them could not carry out all the activities.

Tractors were used on maize, rice, tobacco and sugarcane fields. EE tractors were common on maize and tobacco fields because the soils were lighter. The presence or absence of MM tractors on a farm was influenced by both the soil type and by the affordability to the user. MM tractors were common on clayey rice and sugarcane fields where the users had relatively higher incomes. These clay fields required more robust machines, a characteristic which the EE tractors on average, did not possess to an appreciable extent.

9.3.3 Research question 3

In what ways are MM tillage technologies distinctive from EE ones?

The lifespan, efficiency, breakdown frequency, cost, physical ratios, profitability, user satisfaction, environmental effects and impact on the health of users were all critical characteristics for the user and were examined in Chapter 7. These characteristics were distinctive for MM and EE power tillers and tractors under the different OCs. In general, whilst MM machines were made of high quality and durable materials, they were more expensive to purchase. For instance whilst an average MM power tiller could last for between 7 and 12 years, their EE counterparts had an average lifespan of 3 to 4 years. Whilst MM tractors had an economic life of up to 10 years, the EE ones could manage between 4 and 6 years. The technology in use in terms of engine, gear box and lighting are much simpler for EE machines than for MM ones. Generally, EE power tillers were heavier and had an average horsepower of 15 compared with MM power tillers which were lighter in weight and had an average horsepower of 14.

There are also high levels of breakdown among EE machines. However EE machines from India are usually more resilient than the Chinese ones. Gears and engine parts in MM power tillers were firmly fitted and there were rarely oil leakages during usage. Unlike the MM machines, the gear box and the engine blocks of EE power tillers were usually fragile, and could rarely run for a week without breakdowns, especially in the second year of usage. Engine overheating is also common for EE power tillers. EE tractors on the other hand had relatively lower average horsepower of 60, compared with the MM ones which averaged 73Hp (See Chapter 7). EE power tillers consumed more fuel and lubricants per acre than MM ones. On per acre bases, the output of MM power tillers and tractors per day were consistently higher and required fewer man hours per acre when compared with EE ones. Fuel and lubricant consumption for MM and EE tractors were not significantly different, except for a couple of brands from EE sources which were known to be fuel inefficient, for example Farmtrac from India. During operation, MM tractors were more stable on the field than the EE ones. The MM machines also had a reputation of making very straight furrow during ploughing.

In comparative terms, MM machines were capital intensive while EE ones were labour intensive regardless of the scale. The output-capital ratio were in most cases averagely higher for EE machines than MM ones. That is to say, the efficiency of a unit of EE capital used was greater when compared with the efficiency of a unit of MM capital used.

Returns to the labour intensive technologies from the EEs were higher at a lower scale (power tiller level) than they were at a higher scale (tractor level). Under full capacity utilisation, EE power tillers were in general more profitable than MM ones. Aside from one out of the four operating conditions for tractors where EE machines were found to be more profitable than MM ones, MM tractors generally performed better in terms of profitability. The challenge posed to EE tractors in some instances is the fact that they break down often and yet the spare parts are difficult to find.

On average, it costs twice as much to buy an MM power tiller when compared with an EE one. The ratio widened further when considering a comparison between MM_1 and EE_0, to 3:1. The ratio for MM and EE tractor acquisition and replacement costs were similar to those observed for the power tillers with slight differences across the different OCs. Maintenance costs (costs of spare parts and repair costs) were generally higher for MM machines in terms of actual usage. However, when the rated capacities are considered, some EE machines under OC4 and OC5 for instance have their maintenance costs rising quickly.

The all important issue of profitability as a driver of investment is depressing. Aside from power tillers where at full capacity we see positive profits, most of the tractors regardless of their source do not post positive benefit-cost ratios (Chapter 7). This brings up the question of why farmers would want to continue to invest in a capital good which in the first place is not profitable? The value of an acre of work done by a power tiller in this study has been computed using how much farmers receive when they rent out their machine. This value has been argued by some farmers to be lower than the actual value of the service they provide.

Thus the decision to rent their machines out has philanthropic underpinnings. It is a gesture to help other small scale farmers. Their main objective for buying their machines is to use them on their own farms. And so the real payment for the machine comes from the contribution the power tiller or tractor makes to the crops produced. There is a further possible explanation. They rent out the machines to cover marginal costs (since they have purchased them anyway, and don't have to bother about recouping capital costs). Nonetheless, the relative profitability suggests that at both actual and full capacity EE power tillers are more profitable than MM ones. On the other hand MM tractors are in general more profitable than EE ones.

User satisfaction had mixed outcomes across scale and source depending on the character under review. Nonetheless the general trend was that while users of EE were happy about the low cost nature of owning and maintaining their machines, MM users were particularly happy about the quality, durability and the peace of mind that comes with low levels of breakdown frequency. There were also critical concerns about availability of spare parts. Whilst power tillers from EE had easy access to spares, MM power tillers were lacking in spare parts supply. On the contrary, MM tractors and MM tractors adapted to the EE environment had spare parts available. However, EE tractors especially some of the EE_0 had a poorly functioning spare parts market - a case in point is YTO from China. There were also slight differences in terms of the quality of output, usually in favour of MM machines but sometimes the other way round depending on the tillage operation in question.

EE machines had higher negative effects on the environment: by using higher quantities of lubricants and fuel they release more by-products into the soil. EE machines vibrate more and contribute more to noise pollution. The high vibration and noise that EE power tillers especially generate have dire consequences on the health of users (see Chapter 8).

9.3.4 Research question 4

Do the inherent distinctive characteristics thereof, (if any), of EE tillage technologies help address the needs of resource constrained farmers and other participants in the value chain and hence reduce poverty?

The first and most important point here is that EE machines and their spare parts are low cost and so poorer farmers can afford them. For the poor, generation of employment and incomes is important. In satisfying these needs, more jobs must be created. And for more jobs to be created output must grow in a manner that encourages higher levels of labour participation along the value chain. Given a fixed amount of capital and acquisition costs, different quantities of power tillers and tractors from MM and EE can be purchased under each OC. Simulations on output growth, employment and capability building outcomes when economic agents choose to spend resources on either MM or EE technologies suggests that the latter gives more desirable outcomes on the variables of interest (see Chapter 8).

a. Tillage output and incomes

If land resources are not a constraint, and other inputs such as seeds, fertilizer and labour are available to the farmer, then with a fixed sum of capital, more EE technologies can be procured regardless of the OC, and area cultivated can be expanded more than if MM machines were bought. For instance, under OC1, with an amount of TSH23 billion, 6,708 power tillers could be bought from EE sources on average. This same fixed capital can only bring in 3,207 power tillers from MM sources. The 6,708 EE power tillers are capable of tilling 535,000 acres of land, as against that attainable by the MM machines of 338,000 acres. Assuming productivity of land is similar across farms; then the EE power tillers can support the production of more bags of rice than the MM ones. This will translate into more incomes that are shared across more farming households - an important point for inclusive growth. Similar trends are observed for the other OCs (See Chapter 8, Table 8.10 to 8.11).

b. Employment creation and capability building

Directly derived from point (a) above are the various forms of employment that are generated as the machines to be procured by a fixed capital are imported - more dealers, operators and repairers are needed if EE machines are chosen. For instance under the same OC1, dealers required to handle (import and distribute) the EE and MM machines are in the ratio of 2:1. Similar ratios are observed for repairers and operators needed to maintain and man the machines. As more people get the opportunity to participate in the import market, repair the machines or use them on farms, capabilities are built along the value chain.

c. Lower entry costs for users

One of the main barriers to entry and exclusion of the poor from owning power tillers and tractors are the cost associated with them. Estimations in Chapter 8, Sub-section 8.3.1 indicates that EE power tillers are relatively low cost. And that in relation to farm profits across the four different crops studied, a farmer under any of the systems desiring to raise money to buy a tillage technology could do so quicker if he/she considered EE machines.

d. Access to repairers, reparability and nature of market

Generally, the high levels of breakdown of EE machines allow mechanics the opportunity to continually work on the machines (See Chapter 7; Sub-section 7.5.3). And as they do so repeatedly, they build technical capabilities through learning by doing. This situation occurred mostly with Chinese power tillers which broke down often. On the contrary, MM machines such as those from Japan rarely break down, and so repairers do not have enough opportunity to familiarise themselves with the technology and master the art of repairing them. The consistent breakdown of EE machines in itself is not a good thing. However, the opportunity it gives for capability building is a bright spot.

Consequently, it was easier for EE users to get access to repairers than their MM counterparts. On average an EE power tiller owner could access a repair shop within a 1.8km radius whilest MM users had to travel an average of 2.9km radius. Similarly, EE tractor repairers were within 8.2km whilst their MM counterparts were 29.6km from the home of the user. These distances were statistically significant and have obvious implications on travel cost and time of the poor farmer. For some EE tractors from India, the engines had been considerably simplified for easy repair. One such tractor is the Swaraj which uses the hammer mill technology. This technology allows repairers to mend one cylinder of the engine per time without dismounting the whole block (See Chapter 7).

Currently EE machines, especially power tillers and some tractor brands have outlets and dealers very close to the users (Chapter 6). This makes it easier for farmers to go to the shops and transact business including familiarising themselves with what is available on the market. These same shops have spare parts for EE power tillers. The springing up of such outlets is mainly due to the low cost of the machines which makes it easier for entrepreneurs to enter the business. The proximity of such shops to the users means that farmer travel time in search of spare parts for EE power tillers is reduced. This advantage may however be eroded if the frequency of breakdown of the machine is very high. For example in the Ubaruku rice production enclave in the Mbeya region, five out of six dealers in spare parts specialised in the sale of EE power tiller products. This creates easy access for the poor farmer.

e. Support for less profitable crops like maize

EE machines (tractors in particular) were predominantly found on maize farms. It is important to note here again that maize is not only an important food crop, but also cultivated by a large proportion of crop farmers in Tanzania. Among the four crops considered in this study, maize is the least profitable on per acre basis. Consequently, incomes of maize farmers are comparably lower. Maize farmers within our sample especially those in the Dodoma region operate under very precarious and unpredictable weather conditions. Maize is mainly rain-fed and so farmers engaged in it cannot crop twice per year if the rainfall pattern is uni-modal (a climatic condition which is quite common in Tanzania). This important environmental constraint cuts back farmer incomes. The fact that EE tractors are low cost means that relatively lower income maize farmers can afford them. (See Chapter 7, Table 7.1).

9.4 Implications for theory

This study makes some important contributions to the various bodies of theories relating to the concepts of appropriate technologies in a changing geography of innovation development and production across the globe from the traditional North to South. First, the potential outcomes of SSA engagement with Emerging Economies (China/India) are addressed (Khan et al. 2009; Morris & Einhorn, 2008; Kaplinsky et. al, 2007). Second, the distinctive nature of emerging economy-sourced Below the Radar Innovations (BRIs) is discussed. Here we pay attention to the view that because technologies are socially constructed those adopted/adapted from sources with similar characteristics could work better for SSA (Clark, et al., 2009). Third the possibility that Schumacher tenets of technology transfer to developing economies may converge with those of pure Schumpeterian machinery are also examined (Kaplinsky, 2009). Fourth, the implicit absorptive capacity issues raised by Mmari and Mpanduji (2014) as a limiting factor to the success rate of frugal innovations are given some attention here (See Chapter 3). Fifth we respond to some of the questions raised by Biggs et al., (2010) in relation to

Chinese mechanisation technologies: the role of public policy; the importance of increasing markets for technology based services; and the income distributional outcomes. We discuss these five areas in turn.

9.4.1. The impact of China/India-SSA engagements

This empirical study has brought into the discussion the uncharted course of how Chinese and Indian capital goods (in this case tillage technologies) can directly affect poor producers (farmers). Earlier studies by Khan et al. (2009) and Morris & Einhorn (2008) concentrated mainly on consumer goods and on China in particular in other sectors. Similar to the results obtained by Khan et al. (2009) in Cameroon and Morris & Einhorn (2008) in South Africa, this thesis finds that Chinese and Indian capital goods contribute to increased productivity on farms through area expansion; capability building and employment creation at the farm level as well as along the supply chain. The Indian and Chinese capital goods are more complementary and less competitive in the sense that they have not entirely removed advanced country power tillers and tractors from the system. They are filling a gap by meeting the needs of poor farmers who do not have enough money to purchase expensive machines and cultivating rice on small scale and maize on medium to large scale in areas where the soil texture is lighter. They are however out-competing second-hand machines from advanced countries. This is because the second-hand machines do not have warranty and rarely benefit from bank loans.

9.3.2. The BRI literature

This thesis finds that some of the characteristics identified by the BRI literature are met by emerging economy power tillers and tractors, whilst others are not. Clerk et al (2009) suggests that several decades of investment in the development of new technologies which are fit for purpose by emerging economies for their own environments could trigger benefits in other developing countries (see Chapter 3). The technologies coming from India and China are significantly different from those from the well established firms in advanced countries. They are low cost and sometimes with simplified operational requirements to suit the low skills in low income economies.

The recognition by the BRI literature that low-income economies have unreliable infrastructure and thus require more robust machines is crucial. Unfortunately, the quality of some of the machines coming from the emerging economies is very low. They are fragile, breakdown often and sometimes spare parts to keep them running are difficult to find. Because of their fragile nature, higher skill levels and attention is required to keep them running. There are however slight differences in the challenges presented by Indian and Chinese capital goods. The incidence of breakdown of Chinese machines (usually power tillers) is high compared to Indian machines. However, the Chinese suppliers make available relatively cheaper spare parts that are easily accessible and help circumvent the problem. Some Indian machines (usually tractors) breakdown often but there is limited supply of spare parts and this makes it impossible for users to manage the machines.

9.4.3. Schumacher meets Schumpeter

Kaplinsky (2009) argued that emerging economy technologies possessed certain characteristics that could merge Schumacherian and Schumpeterian tenets. This thesis contributes empirically to this theoretical view. That is, the idea that both poverty reduction and distribution can be enhanced in developing countries if they had access to labour intensive technologies and produced products which were low cost and accessible to low income consumers (see Kaplinsky, 2009) is seeing some day light in Tanzanian agriculture, as was the wish of Schumacher. However, the 'charity' approach adopted by the appropriate technology movements supported by Schumacher is not the main driver of this change. For instance the introduction of Japanese power tillers in the early 2000s in Tanzania through aid, failed to create the needed levels of access to farmers. However, when more affordable Chinese power tillers entered the market, we have observed the annual import of power tillers climbed from about 100 pieces per annum in 2005 to 3,325 in 2010. This tremendous growth has not come about by chance; the Schumpeterian motor is at work.

The low cost nature of emerging economy machines has not only met some of the latent demand for technologies, it has also made financial institutions[43] become interested in giving loans to farmers who in the past would have not qualified for it. Thus an effective demand is being created. These conditions are still in embryonic development, it is work in progress and with time we may well see a buoyant market where relatively low income consumers can participate fully.

As advocated by Schumpeter (1939), we have seen the entrepreneurial drive within the communities under study increase, and disproportionately higher for those engaged in the dealership of emerging economy machines than advanced country ones. Through learning by doing, as a result of gaining access to the machines, some level of skills and capabilities required to develop ideas and make innovations work are also being developed within the communities where power tillers are found.

9.4.4. Absorptive capacity

As noted in Chapter 3 of this thesis, the ability of a firm to recognise the value of external information, assimilate it and apply it to commercial use is known as its absorptive capacity. The findings in this study corroborate those obtained by Mmari & Mpanduji (2014) that there are capacity and knowhow limitations when it comes to the operation and maintenance of technologies. These capacity shortcomings of users, operators and repairers are crucial for emerging economy machines because of their distinctive nature when it comes to quality. Mmari & Mpanduji (2014) showed that there was lack of preparation in some cases by users through training and capability building before the purchase of power tillers. We however find that the lack of knowhow is not always due to

[43] In some cases central government supported the capitalisation of these financial institutions specifically to lend to farmers

the unavailability of training programmes. The training programmes to prepare farmers before or just after purchasing equipment exists but sometimes farmers are uninterested or deem it too expensive for them to commit. There are training programmes which are being offered by some dealers but some farmers refuse to participate even though it is free. Other training sessions are being offered by government institutions at a fee but farmers find it difficult to make time for it. This presents more questions for theory, especially in terms of understanding the incentives which can generate user interests in training programmes for capability building.

9.4.5. Diverse patterns of mechanisation and value chain impacts

Biggs et al. (2011) called for a reopening of the mechanisation debate in the developing world which has been dormant for decades. This thesis does so with some important points of departure and addresses some the issues pertaining to the role of government in an increasingly private sector dominated market; the significance of increasing markets and distributional outcomes of emerging economy technologies. First this thesis moves away from the usual comparison of rudimentary tools and animal power with power tillers and tractors. We compared advanced country power tillers with emerging economy ones in a more nuanced way. We have established that regardless of the source of power tillers and tractors, they are in grades which reflect quality and cost. Thus from the same source more optimal mechanisation choices could be made for different users.

Our results corroborate those of Biggs et al. (2011) with respect to the failure of machines from more matured markets like Japan and Korea to meet the cost requirements of users in South Asia. However, despite India's limited role in meeting the mechanisation needs of small farmers in South Asia, as elaborated by Biggs et al. (2011), we find their medium sized tractors becoming very important for small to medium scale maize producers in Tanzania.

Government's role in Tanzania in supporting these diverse forms of mechanisation emanating from Chinese and Indian machines is taking a bigger scope, but with more focus on a market approach. That is whilst government financial support for importation of machines and their purchase by users is subsidised, such support are mainly passed through commercial banks which establish the viability of given out such resources. Because of the low cost nature of Chinese and Indian machines, we are seeing some expansion in the market demand and this has ramifications for the size of the value chain. More people are now needed for dealerships, servicing and operation and this creates more avenues for employment. On the question of incomes and distribution, we find that the sorts of employment being created are those accessible to the poor and thus ensuring desirable distributional outcomes.

9.5 Implications for policy

Emerging economy power tillers and tractors are generally not always economically more profitable than matured market ones (Chapter 7). The EE machines did not also show positive performance in relation to the environment and health of users. However, we have seen their diffusion rates rising in Tanzania recently (Chapter 5). These findings suggest that the EE machines may be socially more desirable, despite some supply chain challenges. Policy is required to address market imperfections related to regulation, manufacturing, transfer process, user absorptive capacity, credit policies and information asymmetry if the poor are to derive maximum benefits from EE machines. We shall consider these in turn bearing in mind that some of the policy instruments can be carried out independently by the Tanzanian government, others will require collaboration with local partners in the value chain, and yet some policies will require the indulgence of the governments of other countries (development partners) to make them work.

9.5.1 Regulatory policies

Government as a regulator performs two main roles: maintenance of standards; and application of monetary instruments to support poorer users. Stricter enforcement of standards testing rules and information flow between the testing office and potential buyers needs improved regulation. Current standards testing regimes do not mandate importers to test their machines. Changes to this status quo are required to ensure that specifications in machine manuals present the true quality of machines.

Recent proposals to develop a mechanisation policy for Tanzania could be a vehicle for addressing regulatory gaps. The policy could be used as a tool for setting quality bench marks. These bench marks must however be considerate of the fact that demand for higher engineering quality will come with machine price increases. The standards should be moderate, recognising many users are capital constrained and any bench mark which eliminates emerging economy machines could inhibit access.

The development of an accurate bench marking regime will require strong collaboration amongst officers at the Mechanisation Department, Testing Officers, Project Managers of Financial Institutions, Dealers, Manufacturers (if possible) and Farmer Group leadership to ensure that the interest of all agents are catered for. There should be a strong participation among all stake holders to ensure that the right framework for determining what is appropriate is generated. When these bench-marks are clearly defined government institutions can then be charged to enforce them.

9.5.2 Manufacturing policies

Government policies which target manufacturing regimes to create incentives for an improved value chain are two pronged. First government policies that ensure that manufacturers outside the country produce standardised machines and genuine machine parts are required to curb the importation of inferior products. Second policies which facilitate local manufacturing are also required to build capability and core competence within the country. Manufacturers abroad especially those from emerging economies must be engaged through dialogue to ensure that they produce and export machines and spare parts with minimum quality standards to Tanzania. These minimum quality standards should reflect the bench-marks discussed in the previous sub-section. The Tanzanian Embassies in China, India and other emerging economies could be used as conduits for such negotiations.

As discussed in Chapter 2, both China and India are involved in various forms of aid targeting poverty reduction in Tanzania. Some of these aid resources should be spent in enhancing and facilitating Tanzania's ability to make an appropriate tillage technology choice. Resources accruing from Chinese and Indian aid to Tanzania could be channelled into creating platforms for Tanzanian Mechanisation Officials and Businessmen to meet with manufacturers with a view of establishing a memorandum of understanding of what constitute appropriate tractors and power tillers for Tanzania. For instance when India granted Tanzania close to $50 million for the importation of farm machinery, the machines brought in were predominantly Farmtrac, which our study have demonstrated to be less efficient when compared with Swaraj. Farmtrac was chosen despite the fact that its acquisition cost is comparable with Swaraj and besides Swaraj has a more reliable spare parts regime and more simplified engine for easy repair. A more appropriate choice could have been made from the same country. These are areas where decision makers in Tanzania may need help and aid resources could provide such support.

Since negotiations must take cognisance of the fact that increases in quality comes with additional cost the team responsible for such discussions should be armed with the basic fact that almost all power tiller users rarely use them to plant seeds, weed or to harrow, presently. In future they may use them for such activities but currently that is not happening. They mostly use them for primary tillage like ploughing and rotavation. Thus the attachments for these secondary tillage activities can be traded-off for improved quality of the engine and gearbox at least in the short to medium term. This will also help address some of the negative environmental and health effects.

With regards to local manufacturing, policies which relates to ensuring that the tax incentives enjoyed by those who import machines must also be extended to them. And in exchange, government must insist that private companies especially, develop machines that are appropriate for low income farmers in Tanzania. In the same vein, private manufacturing firms trying to enter the business who agree to take the tax incentives should be bound by the agreement to manufacture the spare parts that are difficult to find on the market. This may require further government support for them to obtain the manufacturing license from the parent companies. The existence of cordial relationships between Tanzanian government and those of the emerging economies as demonstrated in Chapter 2 should facilitate such negotiations. As a starting point for local manufacturing, companies could target the production of parts whose engineering and technical requirements are low. For instance power tiller and tractor trailers for haulage have very low engineering barriers and could be easily fabricated by local companies. The challenge is about the cost of manufacturing them locally. At the initial stages, local companies may have higher overhead costs, and may be out-competed by imported once. Removal of subsidies on imported trailers to ensure that local companies have the briefing space to build the needed competence will be useful.

Again, it is surprising to know that at least two companies engaged in some form of local manufacturing activities to produce power tillers and tractors are targeting Spanish and British technologies. This comes as a surprise when we find that the Chinese and Indian machines are actually the ones creating the needed paradigms. Prior to licencing of manufacturing companies, government can have a clause in such agreements to ensure that the machines manufactured are within the reach of the users in terms of cost. This does not entirely rule out the need for the development of competence in the manufacture of advanced country machines. It only suggests that the product mix of all producers should pay more attention to emerging economy machines since they are more socially desirable.

9.5.3 Policies which target transfer and diffusion processes

The main challenges associated with the transfer are those related to the inadequate supply of spare parts of a particular kind, especially those for tractors from India in particular and sometimes China and high cost of spare parts, which makes most of the machines economically unprofitable. Second there are challenges with the supply of advanced country power tillers and spare parts and this inhibits farmers who want to upgrade after using the emerging economy machines and accumulating some resources. The main reason why some companies refuse to supply spare parts of a particular kind is the fact that not all spare parts enjoy the tax incentive regime for agricultural machines.

In order that the tax regimes are applied appropriately to protect the interest of government and genuine traders importing spare parts for the agricultural sector the Tanga Port could be used as the main entry point of agricultural machinery spare parts instead of the Dar es Salaam Port which is very busy and may reduce attention paid to this issue. This change could allow port officials enough time to examine who is bringing in what and for what purpose. On the issue of upgrading, the main confounding factor is the limited number of importers who have license to bring in advanced country power tillers from Japan, Korea and Thailand. There are also issues about the level of effective demand, but it is currently growing. To ease the stickiness in supply, little can be achieved unless government support private firms through negotiations to obtain these licenses using the diplomatic relations they have with those countries in question.

9.5.4 User absorptive capacity policies

For absorptive capacity to grow and mature, some extension, training and skills development for users and their immediate networks of operators and repairers are needed. The fragile nature of the emerging economy machines means that skill requirements for operation and maintenance should be high enough for them to attain their expected lifespan. As noted by an engineer (Chapter 7):

> "...in the Tanzanian situation where capital is scarce, cost innovation is inevitable. Though innovating in the cost sense may sacrifice some level of quality, if operators are properly trained to know the depth, speed and draft force to operate, maybe some of these Indian and Chinese machines may last longer than they do today...it will however be interesting to know how much it costs to train an operator properly as compared with quality reduction in machines to make them affordable and which way we should look as a country..." (Key informant interview with SUMA-JKT engineer, 2012).

In the view of the engineer if we establish the tipping point between how much it costs to train users, operators and repairers to handle fragile machines rather than spend more resources on buying expensive machines it could give directions for future polices. Whichever way we look at it, training is important even if it is not targeting the management of fragile machines. But the question is what forms of training could be appropriate for users giving the limited resources available to the state and the farmers themselves?

Further considerations to be made, or require government interventions which are instructive has to do with whether farmers should be free to buy whatever brand of machine he or she likes. Or there should be a conscious effort to recommend and influence users in a particular geographic location growing particular crops on similar soil regimes to adopt particular models which have been found to work well under those conditions. Any steps in this direction may be controversial and could be seen as crossing the paths of a free market economy. However, I would recommend that it should be given a thought since it is easier to develop a well-functioning market, repair and operational skills regime for fewer brands than when every other farmer seems to have a different machine that requires its own sets of skills and supply chains. The latter scenario presents a jack of all trades master of none regime which may breed thinly spread competence and capability which cannot deal with difficult challenges.

9.5.5 Credit policies

Improvements in financial intermediation are needed to trigger inclusive growth. The smallholder farmer, who is capital constrained usually go in for Chinese power tillers which are of low quality and may not have warranty. Banks do not finance the purchase of such machines. With evidence from the field suggesting that these Chinese power tillers post positive profits, banks have to redo some number crunching to see whether exclusion using the warranty criterion is still valid. Additionally the minimum farm size requirement for farmers to qualify for credit from financial institutions tends to exclude a number of asset poor farmers operating less than 10 acres using power tillers or less than 40 acres using tractors. Meanwhile, prices of power tillers and tractors from emerging economies and advanced countries differ significantly. There should be a change in banking regulations to reflect these price differences: the universal 10 and 40 acre minimum for all buyers are disadvantageous to farmers who demand emerging economy machines which are low cost.

9.5.6 Information asymmetry

There are three important links within the value chain where information flow is inadequate. First manufacturers do not know about the needs of users and their operating conditions. Second, dealers are sometimes not sure why they cannot get hold of particular spare parts for onward distribution. Third, users do not know about all the available technologies and sometimes the exact places where they can find spare parts. Government policies and interventions which seek to bridge this information gap will certainly help. Trade is about information: knowing what to produce as a manufacturer and in what quantities; knowing what to distribute as a dealer and were to get suppliers; and finally knowing what is available and where to get what to buy as a consumer.

Through field trials, CAMARTEC has accumulated a lot of information on Tanzanian soils and the suitability of machines with different tensile strength. A lot of resources could be saved if manufacturers collaborated with this government agency (CAMARTEC) through data and information sharing. This will not only ensure that the cost of machines do not unduly rise because of spending on an information gathering when the data set already exists, but also speed up the process of manufacturing machines which are fit for the purpose of the Tanzanian terrain. Central government through its diplomatic relations with the countries of interest (China/India/Pakistan) should engage the business community through their chamber of commerce to fashion out modalities as to how such information can be shared for mutual benefit.

Whilst some dealers knew why some spare parts were not easily obtained from manufacturers, others did not know at all. Some dealers actually thought I might know why this problem existed (Chapter 7). They continue to make contact with manufacturers without any feed-back. For instance a dealer in tractor spare parts in Morogoro planned a visit to India in 2013 to find out why Farmtrac spare parts were not available. This is certainly an expensive trip which can be avoided if state apparatus of representing Tanzania in India can be called to action. For some of these cross country challenges, government interventions through the use of experts at their mission abroad can help save the dealers some money and time. This is an area where government policy can help, but can only happen if there is close collaboration with the dealers to know their pertinent problems.

The desirable thing is for farmers to get access to affordable machines, use them for production; expand output and then where possible graduate to the use of high quality machines (Chapter 8). There are however information constraints.

Moving forward, district mechanisation officers could collect and share information on venders and what they have on sale with other mechanisation officers in other districts. This way, when farmers intending to buy machines make initial discussions with their district mechanisation officers, they would have some data to share for appropriate procurement processes to occur.

9.6 Directions for future research

There are a number of relevant issues that this study could not deal with, or stumbled upon but fell a little out of its scale and scope. These issues ranging from data points to other sectors within the economy and beyond will require further attention. This sub-section presents the areas this study could not tackle and provide pointers as to the kinds of research that could help understand them and also advance theory.

9.6.1 Completing matrix for discussion and outcome of new entrants

The set-up for this study in terms of the matrix of technology categories, scale of operation and operating conditions generated 20 distinct cells. This study was able to study 16 of the 20 typologies. The other four were not feasible, generally because of lack of data on those machines. Specifically, MM_0 and MM_1 machines under OC2 (maize intercropped with pulses on sandy soils under rain-fed conditions); EE_0 under OC3 (maize and Tobacco intercropped with vegetables on loamy soils under rain-fed); and EE_0 under OC4 (rice and Sugarcane on clay soils under rain-fed) were not captured. An additional research that will complete the table could provide a complete picture of all the machines that exists under the different operating conditions delineated. There were new products (tractors especially) from the EEs which this study did not capture, it will be interesting to look at them. Studies in future could consider this area and also include other crops aside from maize, rice, tobacco and sugarcane.

9.8.2 Factors influencing choice

The factors which influence the choice of technique captured in a dichotomy of advanced country and emerging economy tractors and power tillers will also be an area of study to consider. This is critically important because to shape the behaviour of agents in the market, the drivers of their actions must be understood- especially in an attempt to address gaps or imperfections. This will be important if explicit inputs are to be made into the various stages of the technology transfer. Such information will be useful to both manufacturers and importers, with the view of modifying the products and the process through which they transferred to the user. Though this study collected some data that could allow for aspects of such an investigation, it is not presented in this thesis. The data collection exercise could be expanded through more targeted questions which elicit the drivers of choice and user satisfaction. By extension, the factors that influence choice could be expanded to examine the willingness to pay by users for EE and MM machines, and this too, will require further data collection.

9.6.3 Skill gaps

We have also demonstrated that improved skills in the use, maintenance and repair of emerging economy machines have the potential of improving their profitability. Further investigations that will adequately bring out the farmers' need in terms of skill development may help offer some tools for developing training curricula. That is to design training programmes for users; we need to know what they currently do not have and how that could be satisfied. This will help in the development of training tool kits as well as for theory. Again the methods to be adopted in delivering such training and where the training should be conducted will also be crucial; and knowing what users think will suit them is key. A search for such nuanced training requirements can only be done properly through another field investigation- an area which other researchers interested in this field can consider.

9.6.4 Understanding the manufacturers

At different levels, this study calls for government to negotiate with emerging economy producers to improve the supply of spare parts and also quality of products. To enhance the negotiation tools available to the Tanzanian government, an understanding of the manufacturing firms in those emerging economies cannot be overlooked. This area too, will need further attention in future. In order to, produce machines adapted for different markets, manufacturers should know the characteristics of the market in question. Presently, the assumption is that importers of the power tillers and tractors from the EE markets are providing signals about the Tanzanian markets to producers. It will be interesting to know the kind of signals the different producers in China, India and Pakistan are receiving. Are these signals the same? Or do different producing countries have different understandings of what the market is? Are these differences in understanding of the Tanzanian market resulting in mixed supply gaps from the different sources? Are there policy and practice changes that could be implemented to reduce the extent to which low quality spare parts are exported into Tanzania? Could there also be some modifications in the spare parts supply process, so that those which are lacking could be increased? To answer these questions further studies requiring investigators to visit these manufacturing plants could be helpful. The primary concern is the sorts of changes that can be made to improve the machines without increasing acquisition costs significantly.

9.6.5 Lessons for other crops, sectors and countries

The findings here may not be limited to the agricultural sector, but also in other sectors within Tanzania and the agricultural sectors of other countries within the sub-region. Other sectors outside agriculture in other countries may also benefit from this new paradigm of emerging economy-sourced BRIs which have been found useful in Tanzanian agriculture. Research into these issues will also be useful for comparing outcomes within sectors and across countries for broader policy suggestions. We suspect that the importance of EE technologies may not be limited to mechanisation of the maize, rice, sugarcane and tobacco sub-sectors in the agricultural sector. There are also positive signs to believe that other cash crop producers like those doing sisal, cotton, cashew, coffee, pyrethrum and tea could also benefit. Again, EE technologies may not only work for the agricultural sector, but could also find use in other sectors of the Tanzanian economy. Examples are garments and textiles, wood and metal work industries, transportation industry and many more. These areas could definitely benefit from further studies.

Some countries within the East African sub-region and SSA in general have in recent times embarked on new mechanisation drives. For example Ghana, Burkina Faso and Mali have made some investments in the importation of tractors from emerging economies during the last decade. A cross country study using a similar methodology applied in this thesis could help broaden our understanding of how country specific endowments affect the outcomes of EE mechanisation technologies. The different cultures, infrastructural regimes, technological knowhow of users and innovations systems within those countries could influence issues pertaining to technology transfer, penetration, distinctiveness and more importantly inclusiveness and pro-poor effects. This is an area which can be considered in future and the research questions investigated in this study could be tried elsewhere.

9.7 Conclusion

The question of growth in the agricultural sector of Tanzania is important for two reasons. First it is a key conduit for resource distribution and inclusiveness for an otherwise neglected rural population; a greater proportion of the rural population constitute the majority of the poor in Tanzanian society. Second, with relatively higher comparative advantage with regards to crop production in relation to other countries in the sub-region, its success or failure has derived implications on East African food security. To ensure that the agricultural sector grows and play its role as an attractive employment creation mechanism and food security strategy, effective production technologies are needed. The shift of the innovation landscape from the global north to south may hold the key to unlocking the provision of appropriate techniques. The search for such technologies has engaged the Tanzanian policy makers and academics for decades. To push agriculture beyond subsistence and make it an engine of growth, there should be a gradual shift towards mechanising some aspects of production. Primary tillage such as land preparation could be mechanised in instances where the topography of the land permits. Tanzania does not possess the industrial capability and core competence to produce mechanisation technologies like power tillers and tractors. In the short run, such capabilities are not likely to be developed. Therefore there is the need to transfer these technologies from abroad.

An earlier attempt to transfer power tillers and tractors from advanced countries yielded minimal results, especially for the resource-constrained small and medium scale farmers. However, we are witnessing a historically important change in the geography of innovation and manufacturing competences from the global North to the global South. This global shift of centres of innovation from North to South has important ramifications for technology generation and use. Emerging Economies in Asia especially China and India are leading the way in this new paradigm. This new dynamic could offer poor producers in SSA an opportunity to select from small scale and low cost machines which are fit for their operating conditions, nature of infrastructure, skill sets and capital endowments.

It has become more important now than ever that the widening market presents the farmer with choice sets which must be carefully considered. There is a choice to be made between machines coming from the developed world (capital intensive) and those from emerging economies (labour intensive). Whichever of the two choices is made comes with their own costs and benefits. There are distributional, inclusiveness and pro-poor objectives on the policy agenda of Tanzania. Thus in making this choice, the target is to ensure that the technologies favoured contribute to meeting these policy objectives. Once a choice is made, the technologies are ready to be transferred and diffused. This process of technology transfer requires a well-functioning market that consists of importers, distributers, repairers, financial institutions and users. These markets are sometimes bedevilled with imperfections which must be addressed if more profitable technologies are to be diffused.

It is essential to recognise also that in transferring techniques from abroad, the choice sets available are not infinite, and not all the choices in the finite set are efficient (Clark, 1985). Some efficient technologies may also be inappropriate (Kaplinsky, 1990). To make the most out of the available options requires a careful selection underpinned by a depth of understanding of user needs. User technological needs are shaped by the dynamic interrelationships among their resource endowments, cultural endowments, technologies available and institutions (Ruttan, 2001). The nature of production infrastructure, skill sets of labour, the cost and availability of capital and the level of development of supporting institutions such as finance, insurance and government regulation within the markets are very critical (Mmari & Mpanduji, 2014).

Thus, the introduction, successful adoption, adaptation and use of mechanical power (power tillers and tractors) on farms transiting from subsistence to small and medium scale commercial farms can be very challenging. This is very much so especially in a developing country context where capital is scarce and unskilled or semi-skilled labour is relatively abundant and there is paucity of basic infrastructure. (Eicher & Baker, 1982). There are contestations about the rationality of introducing machines when there is unemployed labour to carry out farm activities (ILO, 1973). Technologies which tend to absorb the surplus factor of production, i.e. Labour is key (Bhalla, 1981). However in the case of Tanzania where land is also in relative abundance, such contests are minimal. And in fact while some technologies may sacrifice some jobs at the initial stage, they may open up more jobs in other stages of the production process (Stewart, 1977). Moving forward, other important barriers to successful mechanisation by smallholders in particular relates to the scale of operation and how to manage excess capacity of equipment (power tillers and tractors) (Kaplinsky, 1990). The EE sources of machines may not address all the tensions raised here, but in as far as access for low income groups are concerned they provide a stepping stone for the poor farmer.

References

Adelman, I. & Morris, C. (1988). *Comparative Patterns of Economic Development, 1850–1914.* Baltimore, United States: John Hopkins University Press.

Agrievolution. (2014). *Agrievolution.* Retrieved August 10, 2014, from http://www.agrievolution.com/PDF/2014-02_WorldMarketForTractors.pdf

Agri-Food Canada. (2012). *An Overview of the Canadian Agriculture and Agri-Food System.* Ottawa, Ontario: Her Majesty the Queen in Right of Canada, 2012.

AICD. (2010). *Tanzania's Infrastructure: A Continental Perspective* . Washington, DC: The International Bank for Reconstruction and Development / The World Bank.

Alden, C. & Alves, C. (2008). History and Identity in Construction of China's Africa Policy. *Review of African political Economy, 1*(35), 43-58.

Alexiusy, A. & Carlssonz, M. (2007). Production Function Residuals, VAR Technology Shocks and Hours Worked: Evidence from Industry Data. *Economic Letters, 96*(2), 259-263.

Atkinson, A. B. & Lugo, M. A. (2010, November). Growth Poverty and Distribution in Tanzania. *International Growth Centre Working Paper 10/0831*.

Bank Of Tanzania. (2012). *Annual Report 2010/2011: Director of Economic Research and Policy.* Dar es Salaam: Bank of Tanzania.

Barker, R., & Herdt, R. (1985). *The Rice Economy of Asia.* Washington, D.C.: Resources for the Future, Johns Hopkins University Press.

Barrett, C. B. (1998). Immiserized Growth in Liberalized Agriculture. *World Development, 5*(26), 743-753.

Benin, S. (2014, March). Impact of Ghana's Agricultural Mechanisation Services Center Program. *International Food Policy Research Institute Discussion Paper 01330*, pp. 1-40.

Bennell, P. (1999). *Learning to Change: Skills Development among the Economically Vulnerable and Socially Excluded in Developing Countries.* ILO: Geneva.

Bhalla, A. (1981). *Technology and employment in industry: a case study approach* (2nd ed.). Geneva: International Labour Office.

Biesebroeck, V. (2003). Productivity Dynamics with Technology choice: An Application to Automobile Assembly. *Review of Economic Studies, 70*, 167–198.

Biggs, S., Justice, S. & Lewis, D. (2011, February 26). Patterns Rural Mechanisation, Energy and Employment in South Asia: Reopening the Debate. *Economic and Political Weekly*, pp. 78-82.

Biggs, S., Justice, S., Gurung, C., Tripathi, J. & Sah, G. (2002). *The Changing Power Tiller Innovation System in Nepal: An Actor-Oriented Analysis (1).* Mymensingh, Bangladesh: Bangladesh Agricultural University.

Bloor, M. (1997). Techniques of validation in qualitative research: a critical commentary. In G. Miller, & R. Dingwall, *Context and method in qualitative research* (pp. 37-50). London: SAGE Publications.

Brautigam, D. (2009). *The Dragon's Gift: The Real Story of China in Africa.* New York: Oxford University Press.

Bruche, G. (2009, April 29). A New Geography of Iinnovation - China and India Rising. *Columbia FDI Perspectives, No. 4*.

Burgess, R. G. (1984). *In the Field: An Introduction to Field Research.* Abingdon: Routledge.

Burke, W. J., Hichaambwa, M., Banda, D. & Jayne, T. S. (2011, March). The Cost of Maize Production by Smallholder Farmers in Zambia . *Food Security Research Project Working Paper 50* , pp. 1-27.

Carr, M. (1985). *The AT Reader: Theory and Practice in Appropriate Technology.* Bath: The Pitman Press.

Ceesay, M. (2004). *Management of Rice Production Systems to Increase Productivity in the Gambia, West Africa.* Ithaca: Cornell University Faculty of the Graduate School .

Chand, R., Prasanna, P., & Singh, A. (2011, June 25). Farm Size and Productivity: Understanding the Strengths of Smallholders and Improving Their Livelihoods. *Economic and Political Weekly, XLVI*(26&27), pp. 5-11.

Clark, N. (1985). *The political Economy of Science and Technology* . Oxford: Basil Blackwell.

Clark, N., Chataway, J., Hanlin, R., Kale, D., Kaplinsky, R., Muraguri, L., . . . Wamae, W. (2009, January). Below the radar: what does the Asian driver economies: have to offer low income economies. *Innogen Working Paper No. 69*.

Clarke, L. J. (1997). *Agricultural Mechanization Strategy Formulation, Concepts and Methodology and the Roles of the Private Sector and the Government.* Rome, Italy: FAO Agricultural Support Systems Division.

Cohen, W., & Levinthal, D. (1990). Absorptive Capacity: A New Perspective on Learning and Innovation. *Administrative Science Quarterly, 36*, 128-152.

Coleman, J. S. (1958). Relational Analyses: The Study of Social Organisation with Survey Methods. *Human Organisation, 17*, 28-36.

Cooper, C., & Kaplinsky, R. (1975). Second-Hand Equipment in Developing Countries: Jute Processing Machinery in Kenya. In A. S. Bhalla (Ed.), *Technology and Employment in Industry* (pp. 129-153). Geneva: International Labour Office.

Cuong, N. V. (2009). Does Agriculture Help Poverty and Inequality Reduction? Evidence from Vietnam. *Agricultural Economics Review, 11*(1), 44-56.

Diao, X., Hazell, P., Resnick, D. & Thurlow, J. (2007). *The role of agriculture in development: implications for Sub-Sahran Africa.* Washington D.C.: International Food Policy Research Institute.

Diao, X., Yeldan, A. E. & Roe, T. (1998). A Simple Dynamic Applied General Equilibrium Model of a Small Open Economy:Transitional Dynamics and Trade Policy. *Journal of Economic Development, 23* (1), 77–101.

Dimitri, C., Effland, A. & Conklin, N. (2005). *The 20th Century Transformation of U.S. Agriculture and Farm Policy.* Washington, DC: USDA.

Dixon, J., Gulliver, A. & Gibbon, D. (2001). *Farming Systems and Poverty: Improving Farmers' Livelihoods in a Chaging World.* Rome & Washington: Food and Agriculture Organization & World Bank.

Dosi, G. (1982). Technological Paradigms and Technological Trajectories. *Research Policy, 11*(3).

Dumont, R. (1966). *False Start in Africa.* London: Andrew Deutsche.

Easterly, W. (2009). Can the West Save Africa? *Journal of Economic Literature, 47*(2), 373–447.

Eckaus, R. S. (1955). The Factor Proportions Problem in Underdeveloped Areas. *American Economic Review, 45*(4), 539-565.

Eckaus, R. S. (1987). Appropriate Technology: The Movement Has Only a Few Clothes On. In *Issues in Science and Technology* (pp. 62-71). Winter.

Edquist, C. & Jacobsson, S. (1988). *Flexible automation. The global diffusion of new technology in the engineering industry.* London: Basil Blackwell.

Eicher, C. & Baker, D. (1982). Rsearch on agricultural development in sub-Saharan Africa: acritical survey. *MSU International Development Paper 1, Michigan State university, USA.*

Ellis, K., Lemma, A. & Rud, J. (2010). *Investigating the Impact of Access to Financial Services on Household Investment.* London: Overseas Development Institute.

Emmanuel, A. (1982). *Appropriate Technology and Underdevelopment.* Chichester: J. Wiley.

Erickson, A. (2012). Peace in Tanzania: An Island of Stability in sub-Saharan Africa. *Research Discourse, 3*(1), 18-31.

European Commission. (2011). *Monitoring Industrial Research: The 2011 EU Industrial R&D Investment Scoreboard and Directorate-General for Research & Innovation.* Luxembourg: European Commission : Publications Office of the European Union.

Fan, S. & Brzeska, J. (2010, December). *The Role of Emerging Countries in Global Food Security.* Washington D.C.: IFPRI.

Fan, S., Nestorova, B. & Olofinbiyi, T. (2010). China's agricultural and rural development: implications for Africa. Bamako, April 27-28, 2010: China-DAC Study Group on Agriculture, Food Security and Rural Development.

FAO. (1966). *Agricultural development in Nigeria.* Rome: Food and Agricultural Organization.

FAO. (2005). *Contribution of Farm Power to Sustainable Rural Livelihoods in sub-Saharan Africa.* Rome: C. Bishop-Sambrook, Agricultural and Food Engineering Technical Report No.2, Agricultural Support Systems Division.

FAO. (2011). Investment in Agricultural Mechanization in Africa. *Conclusions and recommendations of a round table of meeting of experts, 3-5 June 2009.* Arusha, Tanzania: FAO.

FAO. (2013). *Mechanisation for Rural Development: A review of patterns from around the world.* Rome: FAO.

FAO/UNIDO. (2008). *Agricultural Mechanization in Africa: Planning Investment for Enhanced Agricultural Productivity.* Rome/Vienna: FAO/UNIDO.

Farrell, M. J. (1957). The Measurement of Productive Effiency. *Journal of the Royal Statistical Society, 120*(3), 253-290.

Fellner, W. (1961). Two Propositions in the Theory of Induced Innovation. *Economic Journal, 71*, 305-308.

Floor, W. M. (1979). Activities of the UN System on Appropriate Technology. In A. S. Bhalla (Ed.), *Towards Global Action for Appropriate Technology* (p. p 144). Geneva: ILO.

Fonteh, F. M. (2010). *Agricultural Mechanisation in Mali and Ghana: Strategies, experiences and Lessons for Sustained Impacts.* Rome: Food and Agricultural Organisation of the United Natios.

Francks, P. (1996). Mechanizing Small-Scale Rice Cultivation in an Industrializing Economy: The Development of the Power-Tiller in Prewar Japan . *World Development, 4*(24), 781–796.

Gabre-Madhin, E. & Haggblade, S. (2004). Successes in African Agriculture: Results of an Expert Survey. *World Development, 5*(32), 745-766.

Gass, G. & Biggs, S. D. (1993). Rural Mechanisation: A Review of Processes, Polices, Practice and Literature. *Project Appraisal, 8*(3), 157-187 .

Gibb, A. (1988). *Agricultural Engineering Perspective: Celebration of Golden Jubilee 1938-88.* Bedford: Silsoe, Institution of Agricultural Engineers.

Giles, G. (1967). Agricultural power and equipment. *The World Food Problems, III*, 175–216.

Guba, E. & Lincoln, Y. (1989). *Fourth Generation Evaluation.* California: Sage Publications.

Gurak, H. (2003). Hidden Costs of Technology Transfer: Adverse Impacts of Package Deals with Restrictive Clauses. *Yepi Kredi Economic Review, 14*(1), 31-50.

Hatibu, N. (2013). Investing in Agricultural Mechanisation for Development in East Africa. In J. E. Josef Kienzle (Ed.), *Mechanization for Rural Development: A Review of Patterns and Progress from Around the World* (pp. 1-12). Rome: FAO.

Hazell, P. & Haddad, L. (2000). *CGIAR Research and Poverty Reduction.* Washington, D.C.: IFPRI.

Hicks, J. (1932). *The Theory of Wages.* London: Macmillan.

Hodge, J. (1973). *Lifelines* (6 ed.). Colchester: Shire Publications.

Hoekman, B. M., Maskus, K. E. & Saggi, K. (2004, May). Transfer of Technology to Developing Countries: Unilateral and Multilateral Policy Options. *Institute of Behavioral Science, University of Colorado at Boulder,Working Paper PEC2004-0003*.

Hollander, S. (1965). *The Sources of Increased Efficiency: A Study of Dupont Rayon Plants.* Cambridge, Mass: MIT Press.

Holtkamp, R. (1991). *Small Four-Wheel Tractors for the Tropics and Subtropics: Their Role in Agricultural and Industrial Development.* Weikersheim : Eschborn .

Hoogeveen, J. & Ruhinduka, R. (2009). *Lost in Transition? Income and Poverty Reduction in Tanzania since 2001.* Dar es Salaam: Background paper to the Tanzanian Population and Human Development Report 2009.

Houssou, N., Diao, X., Cossar, F., Kolavalli, S., Jimah, K., & Aboagye, P. (2013, January). Agricultural Mechanisation in Ghana: Is Specialisation in Agricultural Mechanisation a Viable Business Option? *Ghana Strategy Support Program, IFPRI.*

IBRD. (1960). *The economic development of Tanganyika.* ., Baltimore, USA: Johns Hopkins University Pres for IBRD.

ICRA. (2012). Indian Tracor Industry: Weak Monsoons Dampen Demand in Struggling Market. New Delhi: ICRA Limited.

IFAD. (1998). *Agricultural Implements Used by Women Farmers in Africa.* Rome: International Fund fo Agricultural Development.

ILO. (1973). *Mechanization and Employment in Agriculture: Case Studies From Four Continents.* Geneva: International Labour Organization.

Imai, M. (1986). *Kyizen: The Key to Japan's Competitive Succes.* New York: McGraw-Hill.

Inns, F. M. (1995). Selection, Testing and Evaluation of Agricultural Machines and Equipment Theory. *FAO Agricultural Services Bulletin No. 115*.

Irz, X., Lin, L., Thirtle, C. & Wiggins, S. (2001). Agricultural Productivity Growth and Poverty Alleviation. *Development Policy Review, 4*(19), 449-466.

Jackson, C. & Palmer-Jones, R. (1997). Work intensity, gender and sustainable development. *Food Policy, 22*(1), 39-62 .

Jafarieh, H. (PhD thesis, 2001). *Technology transfer to developing countries: a quantitative approach.* Manchester, UK: University of Salford.

Jansson, J., Burke, C. & Hon, T. (2009). *Patterns of Chinese investment, aid and trade in Tanzania.* London: WWF.

Jessop, R., Diallo, B., Duursma, M., Mallek, A., Harms, J. & van Manen, B. (2012). *Creating Access toAgricultural Finance: Based on a horizontal study of Cambodia, Mali, Senegal, Tanzania, Thailand and Tunisia.* Paris France: AFD.

Jones, R. & Kimura, S. (2013). *Reforming Agriculture and Promoting Japan's Integration in the World Economy.* Paris: Organisation for Economic Co-operation and Development.

Jörgensen, C., & Persson, M. (2013, February). The Market for Tractors in the EU Price Differences and Convergence. *Factor Markets: Working Paper No. 35.*

Kaplinsky, R. (1981). *Appropriate technology in a Developing Country: The Bakery Industry in Kenya.* Sussex : D Phil Dissertation Submitted at the University of Sussex.

Kaplinsky, R. (1990). *The Economics of Small: Appropriate Technology in a Changing World.* Washington, D.C.: IT publications.

Kaplinsky, R. (2007). *The Impact of China and India on the Sub-Saharan Africa: A Methodological Framewrk. A Framework Paper for the AERC Project on The Impact of Asian Drivers on sub-Sharan Africa.* SSA: African Economic Research Consortium.

Kaplinsky, R., McCormick, D. & Morris, M. (2007). The Impact of China on sub-Saharan Africa. *IDS Working Paper 291*, pp. 1-48.

Kaplinsky, R. (2008). Introduction: The Impact of Asian Drivers on the Developing World. *World Development , 36*(2), 197–209.

Kaplinsky, R. (2009). Schumacher Meets Schumpeter: Appropriate Technology Below The Radar . *IKD Working Paper No. 54.*

Kaplinsky, R. (2010). The Role of Standards in Global Value Chains and their Impact on Economic and Social Upgrading. *Policy Research Working Paper 5396, The World Bank: Washington.*

Kaplinsky, R. (2011, November). Bottom of The Pyramid Innovation and Pro-Poor Growth. *IKD Working Paper No. 62.*

Khan, S. A. & Baye, F. M. (2008). China-Africa Economic Relations: The Case of Cameroon. Scoping Study for the AERC Project. *The Impact of Asian Driers on sub-Saharan Africa: Paper No. SCC 16.*

Khan, S. A., Baye, F. M. & Tange, G. K. (2009). *The impact of China-Africa trade Relations: case study of Cameroon.* Yaounde: African Economic Research Consortium.

Kim, L. (1991). Pros and Cons of Internationational Technology Transfer: A Developing Country's View. In T. Agmon, & M. von Glinow (Eds.), *Technology Transfer in International Business.* Oxford University Press: Oxford.

Kjaerby, F. (1986). The Development of Agricultural Mechanisation in Tanzania. In J. Boesen (Ed.), *Tanzania Crises and Struggle for Survival* (pp. 173-190). Uppsala: Scandinavian Institute of African Studies.

Krueger, A., Valdes, A. & Schiff, M. (1991). *Political Economy of Agricultural Pricing Policy: Latin America.* Baltimore, United States: Johns Hopkins University Press.

Kuboja, N. M., & Temu, A. E. (2013). A Comparative Economic Analysis of Tobacco and Groundnut Farming in Urambo District, Tabora Region, Tanzania. *Journal of Economics and Sustainable Development, 4*(19), 104-111.

Lane, P., Salk, J. E., & Lyles, M. (2001). Absorptive Capacity, Learning and Performance in International Joint Ventures. *Strategic Management Journal, 22*, 1139–1161.

Levin, J. & Mbamba, R. (2004). Economic growth, sectoral linkages and poverty reduction in Tanzania. *background paper for the Tanzania CEM.*

Lewis, W. A. (1954). Economic Development with Unlimited Supplies of Labour. *Manchester School, 22*, 139-191.

Lipsey, R. (1966). *Positive statements Concern What Is, Was or Will Be and Normative Statements Concerns What Ought to Be: AnIintroduction to Positive Economics* (2nd ed.). London: Weidenfeld and Nicholson.

Ludena, C. E. (2010, May). Agricultural Productivity Growth, Efficiency Change and Technical Progress in Latin America and the Caribbean. *Inter-American Development Bank Working Paper Series.*

Lyimo, M. (2011). *Country presentation on Agricultural Mechanization in Tanzania.* Saint Louis: Senegal: Presentation to Workshop on "Boosting agricultural mechanization in rice-based systems in sub-Saharan Africa".

MAFAP. (2013). *Review of Food and Agricultural Policies In the United Republic off Tanzania 2005-2011.* Rome: MAFAP/FAO.

MAFF. (2012b). *Food Balance Sheet FY 2012.* Tokyo: Ministry of Agriculture, Forestry and Fisheries.

Maghimbi, S. (1990). Cooperatives in agricltural development. In O. Norman, & K. Mustafa (Eds.), *Capitalism, socialism and development crisis in Tanzania.* Aldershot: Avebury.

Maghimbi, S. (2006). *The Organization Capacity of Cooperatives for Peasants and Small Farmers and Small Farmers: A View From an Outsider.* Zanzibar, Tanzania: REDET's Training Workshop for Leaders of Cooperatives.

Maghimbi, S. (2010). *Cooperatives in Tanzania Mainland: Revival and Growth.* Switzerland: International Labour Organization and Coop Africa.

Mandal, M., Sattar, A., & Asaduzzaman, M. (2002). *Rural Non-Farm Economy in Bangladesh: Characteristics and Issues for Development.* Dhaka : DFID Bangladesh Office.

Mandal, S. K., & Maity, A. (2013). Current Trends of Indian Tractor Industry: A Critical Review. *Applied Science Reports, 3*(2), 132-139.

Mani, S. (2005). The Dragon vs the Elephant: Comparative Analysis of Innovation Capability in the Telecommunications Equipment Industry in China and India. *Centre for Development Studies, Trivendrum Working Papers 373.*

Mansfield, E., Romeo, A., Schwartz, M., Teece, D., Wagner, S. & Brach, P. (1982). *Technology Transfer, Productivity and Economic Policy*. New York. : Norton & Company.

Mashindano, O., Kayunze, K., da Corta, L. & Maro, F. (2011, June). Agricultural Growth and Poverty Reduction in Tanzania 2000-2010: where has Agriculture Worked for the Poor and What can we Learn from This? *Chronic Poverty Research Centre, Working Papar No. 208.*

Maxwell, J. A. (1992). Understanding and Validity in Qualitative Research. *Harvard Educational Review, 62*, 279-300.

Mbelle, A. (2008). *The Impact of Reforms on the Quality of Primary Education in Tanzania.* Dar es Salaam Tanzania: REPOA.

Mellor, J. (1999). *Faster, More Equitable Growth – The Relation Between Growth in Agriculture and Poverty Reduction.* Washington, D.C.: Agency for International Development.

Menenwa, R. & Maliti, E. (2010). *A Comparative Analyses of Poverty Incidence in Farming Systems of Tanzania.* Dar es Salaam: REPOA.

Mishra, D. (2011). *VST Tillers Tractors Ltd.* Mumbai: Sushil Financial Services Private Limited.

Mkenda, A., Luvanda, E., & Ruhinduka, R. (2009). *Growth and Distribution in Tanzania: Recent Experience and Lessons.* Dar es Salaam: Interim report to REPOA.

Mmari, D., & Mpanduji, S. (2014). Frugal Innovation for Inclusive Development: A Case Study on Power Tillers in Tanzania. *Policy Research For Development.*

MoFEA. (2009). *The Economic Survey 2008.* Dar e Salaam, Tanzania: Ministry of Finance and Economic Affairs.

Mohan, G. (2000). *Structural Adjustment : Theory, Practice and Impacts.* London, New York: Routledge.

Morris, M. & Einhorn, G. (2008). Globalisation, Welfare and Competitiveness: The Impacts of Chinese Imports on the South African Clothing and Textile Industry. *COMPETITION & CHANGE, 12*(4), 355–376.

Moshi, H. & Mtui, J. (2008). *Scoping Studies in China-Africa Economic Relations: The Case of Tanzania.* Dar es Salaam: Economic Research Bureau, 2008;.

Mowery, D. & Oxley, J. E. (1995). Inward technology transfer and competitiveness: The role of national innovations system. *Cambridge Journal of Economics, 19*, 67-93.

Mowery, D. & Rosenberg, N. (1998). *Paths of Innovation: Technological Change in 20th Century America.* New York, NY: Cambridge University Press.

Mrema, G. (1984). Agricultural Mechanization in Tanzania: Constraints and Prospects. In M. &. Siegman (Ed.), *Development of agricultural machinery industry in developing countries.* Wageningen.: Pudoc.

Mrema, G. C., Baker, D. & Kaha, D. (2008). *Agricultural Mechanization in Africa: Time for Action.* Vienna, Austria: FAO.

Msigwa, R. & Kipesha, E. F. (2013). Determinants of Youth unemployment in Developing Countries: Evidences from Tanzania. *Journal of Economics and Sustainable Development, 4*(14), 68-76.

NBS. (2007). *LFS 2006, Analytical Report.* Dar es Salaam, Tanzania: National Bureau of Statistics.

NBS. (2009). *Household Budget Survey 2007.* Dar es Salaam: National Bureau of Statistics.

NBS. (2010). *Tanzania in Figures .* Dar es Salam: National Bureau of Statistics.

NBS. (2013). *2012 Population and Housing Census, Tanzania.* Dar es Salaam: National Bureau.

Nkamleu, G., Gokowski, J., & Kazianga, H. (2003). Explaining The Failure of Agricultural Production in Sub-Saharan Africa. Durban, South Africa: Contributed paper selected for presentation at the 25th International Conference of Agricultural Economists.

OECD. (2008). *Evaluation of Agricultural Policy Reforms in Korea.* OECD.

Paman, U., Uchida, S., & Inabaz, S. (2010). The Economic Potential of Tractor Hire Business in Riau Province, Indonesia: A case of small tractor use for small rice farms. *Agricultural Engineering International: the CIGR Ejournal, 12*(1), 135 – 142.

Patton, M. Q. (2002). *Qualitative Research and Evaluation Methods.* Sage Publications Inc. Thousand Oaks: London, New Delhi.

Pfitzer, M., Krishnaswamy, R., & Genier, C. (2009). *Market Development Investments by Agricultural Input Companies and their Foundations: Transforming Smallholder Agriculture .* Basel, Switzerland: The Syngenta Foundation for Sustainable Agriculture.

Pingali, P. L., Bigot, Y. & Binswanger, H. (1987). *Agricultural Mechanization and the Evolution of Farming in sub Saharan Africa.* Baltimore: John Hopkins University Press.

Prahalad, C. K. (2005). *The Fortune at the Bottom of the Pyramid: Eradicating Poverty Through Profits.* Upper Saddle River, NJ: Pearson.

Rampokanyo, L. M. (2012). *Impact of Animal Traction Power on Agricultural Productivity: The Case of Lowlands of Mohales Hoek District of Lesotho.* Fort Hare, Lesotho: University of Fort Hare.

Rao, R. (2013). *Academia.edu: Tractor Industry Outlook*. Retrieved October 30, 2014, from http://www.academia.edu/3842991/Tractor_Industry_Outlook

RLDC. (2009). *Rice Sector Strategy: Improving Rice Profitability Through Increased Productivity and Better Marketing Focusing on Tanzania's Central Corridor*. Dar es Salaam: Rural Livelihood Development Company (RLDC).

Robson, C. (2002). *Real World Research* (2nd ed.). Oxford, Massachusetts: Blackwell Publishers Inc.

Rutta, E. (2012). *Current and Emerging Youth Policies and Initiatives with a Special Focus and Links to Agriculture.* Pretoria, South Africa: Food, Agriculture and Natural Resources Policy Analysis Network.

Ruttan, V. W. (1959). Usher and Schumpeter on Invention, Innovation and Technological Change. *Quarterly Journal of Economics*, 596-606.

Ruttan, V. W. (2001). *Technology, growth and development: an induced innovation perspective.* Oxford: Oxford University Press.

Rweyemamu, J. (1973). *Underdevelopment and Industrialization in Tanzania: A Study of Pererse Capitalist Development.* London: Oxford University Press.

Sarris, A., Savastano, S., & Christiaensen, L. (2006, June). The Role of Agriculture in Reducing Poverty in Tanzania: A Household Perspective from Rural Kilimanjaro and Ruvuma. *FAO Commodity and Trade Policy Research Working Paper No. 19.*

Schumacher, F. (1973). *Small is Beautiful.* London: Blond and Briggs .

Schumpeter, J. A. (1939). *Business Cycles.* New York: McGraw Hill.

Seluhinga, N. S. (2013). Determinants of the Probability of Obtaining Formal Financial Services in Tanzania. *Journal of Sustainable Development in Africa , 15*(2), 68-80.

Sen, A. K. (1968). *The Choice of Techniques* (3rd ed.). Oxford: Blackwell.

Siemens, J. C. & Bowers, W. W. (1999). *Machinery Management: How to Select Machinery to Fit the Real Needs of Farm Managers. Farm Business Management Series.* Davenport, Iowa: John Deere Publishing.

Simalenga, T. E. (1989). *Simulation model to Predict Field Work Days and its Use in Machinery Selection Under Tropical Conditions.* Copenhagan, Denmark: Unpublished PhD Thesis, Institute of Agricultural Engineering, Royal Verterinary and Agricultural university.

Simalenga, T., Belete, A., Mseleni, N., & Jongisa, L. (2000). Assessing Profitability of Using Animal Traction Under Smallholder Farming Conditions. *South African Journal of Agricultural Extension , 29*, 230-234.

Sims, B. G., & Kienzle, J. (2006). *Farm power and mechanization for small farms in sub-Saharan Africa.* Rome: FAO.

Singer, H., Cooper, C., . Desai, R. C., Freeman, C., Gish, O., Hall, S., & Oldham, G. (1970). *, The Sussex Manifesto: Science and Technology for Developing Countries During the Second Development Decade.* Brighton: IDS Reprints No. 101: Institute of Development Studies.

Singh, P., & Singh, A. (2012). Decomposition of Technical Change and Productivity Growth in Indian Agriculture Using Non-Parametric Malmquist Index. *Eurasian Journal of Business and Economics 2012, 5*(9), 187-202.

Soete, L. (2009). Science, Technology and Development: Emerging Concepts and Visions. *SLPTMD Working Paper Series, 017.*

Solow, R. M. (1956). A Contribution to the Theory of Economic Growth. *The Quarterly Journal of Economics, 70*(1), 65-94.

Starkey, P. (1998). Integrating Mechanization into Strategies for Sustainable Agriculture. *Summery report and recommendations, CTA Seminar, 24-29 November 1997.* Ouagadougou, Burkina Faso : Technical Centre for Agriculture and Rural Development.

Statistics Canada. (2006). *2006 Census of Agriculture.* Retrieved July 25, 2014, from http://www.statcan.gc.ca/ca-ra2006/index-eng.htm

Stewart, F. (1977). *Technology and Underdevelopment.* Hong Kong: The MacMillan Press Ltd.

Sumner, P., & Williams, J. (2007). *What Size Farm Tractor Do i Need?* Atlanta: University of Georgia, College of Agriculture.

Tassey, G. (1992). *Technology Infrastructure and Competition Position.* Norwell, MA: Kluwer.

UNECA. (2011). *Economic Report on Africa 2011: Governing Development in Africa - The Role of the State in Economic Transformation.* Addis Ababa: United Nations Economic Commission for Africa.

URT. (2011). *Tanzania In Figures, 2010.* Dar es Salaam: National Bureau of Statistics and Ministry of Finance.

URT. (2012). *National Sample Census of Agriculture 2007/08: Large Scale Farms.* Dar es Salaam: The United Republic of Tanzania.

USCB. (2012). *The 2012 Statistical Abstract*. Retrieved July 25, 2012, from http://www.census.gov/compendia/statab/cats/agriculture.html

USDA. (2004). *Farm Bill Forum Comment Summary and Background.* Washington DC: USDA.

Van Tho, T. (1993). Technology Transfer in the Asian Pacific Region: Implications of Trends since the Mid-1980s. In T. Ito, & A. O. Krueger (Eds.), *Trade and Protectionism* (pp. 244-249). Chicago : The Univcrsity of Chicago Press.

Vickers, B. (2011). Between a Rock and a Hard Place: Small States in the EU-SADC EPA Negotiations. *The Round Table: The Commonwealth Journal of International Affairs, 100*(413), 183–197.

Walters, D. (2013, March). Soil, Draft, and Traction - The Open Furrow. *Dirt Hog's Companion: Technical Notes 21*.

Whiting, D., Card, A. & Wilson, C. (2011, December). Estimating Soil Texture: Sandy, Loamy or Clayey? *Colorado Master Gardener Program: Garden Notes #214*.

Williamson, J. (1990). *Latin American Adjustment: How Much Has Happened?* Washington: Institute for International Economics.

Wilson, I. M. (2005). Some Practical Sampling Procedures for Development Research. In J. Holland, & J. Campbell (Eds.), *Methods of Development Research: Combining Qualitative and Quantitative Approaches* (pp. 37-51). Colchester: ITDG Publishing.

World Bank. (2013). *World Development Indicators.* Retrieved July 25, 2014, from http://data.worldbank.org/indicator/IT.CEL.SETS.P2

Yamin, M., Tahir, A. R., Nasir, A. & Yaseen, M. (2011). Short Communication Studying the Impact of Farm Mechanization on Wheat Production in Punjab-Pakistan. *Soil Environment, 30*(2), 151-154.

Yoshikawa, Y. (2010). Can Japanese Agriculture Overcome Dependence and Decline? *Japan Focus: 28*.

Zeng, M. & Williamson, P. (2006). *Dragons at Your Door: How Cost Innovation is Disrupting Global Competition.* Cambridge, MA: Harvard Busisness School Press.

APPENDIX: QUESTIONNAIRES

Tilling the Soil in Tanzania: What Do Emerging Economies Have to Offer- Farmer Questionnaire

We are going to ask you a few questions to enable the researcher analyse how different Farm Tractor and Power Tiller Technologies from emerging economies like India are from those coming from Northern advanced countries. This will help us improve our understanding of how these differences will help address the needs of the average farmer in Tanzania. We would also want to learn about how these capital goods get to you and through whom you get them. We assure you that the data collected is purely for academic and policy purposes, and in any publication your identity will be concealed. You have the right to stop answering these questions at any point of this interview. We will however be very glad if you will help us complete this section of our survey.

Date of Interview_____ _____ __________ Start time____:____ End Time____:____

DD MM YYYY HH MM HH MM

Q1	Farmer Name/Company Name		
Q2	Region		
Q3	District		
Q4	Community		
Q5	Locality	*1….Urban 2….Rural*	
Q6	Phone Number		
Q7	Location of Household in the community		
Q8	Is your equipment a tractor or a power tiller?	*1…..Tractor 2…..Power Tiller*	
Q9	Please describe to me what you consider to be an ideal tractor or power tiller for your work (Situation and purpose)- what should the characteristics of a tractor or power tiller which is suitable for you be?		
Q10	Model of Tractor/Power tiller 1..Amec/Donfeng 2...Belarus 3...YTO 4...Escort 5...Europard 6...Farmtrac 7...Fiat 8...Ford 9...Kubota 10...Kukje 11...Mahindra 12...MF 13...Powertrac 14...SAME 15...Siam Kubota 17...Swaraj 18...TAFE 19...Valtra 20...VST Shakti 21...Other Specify…………………		
Q11	What is the Horse Power of your machine	*NB: Please inspect machine if farmer does not know*	

Q12	What type of Driving system does your tractor have? *(To be asked to Tractor respondents only)*	*1...Two wheel* *2...Four Wheel*	
Q13	Country of origin of your equipment	*please write in*	
Q13a	Month and Year of purchase	*write in digits only*	month____ year____
Q14	What was the total cost at the point of purchase (price)	*in TSH*	
Q15	If it was not new how old was it at the point of purchase	*years*	
Q16	Did you take a loan to buy this equipment?	*1.....Yes 2.....No*	
Q17	From whom was loan obtained (Name of Company or person...if person add relationship)?	*a. Name of Person or Company* *b. Relationship if Person*	a.____ b.____
Q18	Principal (How much was the loan)	*TSH*	
Q19	Interest Rate on loan	*%*	
Q20	Over what period was loan supposed to be repaid?	*Years and months (if any)*	
Q21	Have you completed loan repayment?	*1.....Yes 2.....No*	
Q21a	If you were to raise this money from your farming business how long would it have taken you to do so? (years or seasons)		
Q22	Do you think you could have raised this money by yourself?	*1.....Yes 2.....No*	
Q23	Please explain your answer in Q22		
Q24	Did you have to make any down payments before the loan was given? If yes please state amount	*a. 1.....Yes 2.....No* *b. Amount (TSH)*	a. ____ b.____
Q25	General comments on loan acquisition process (narration of how the process went on)		
Q26	If not loan how did you raise the money? (Please describe - if sale of crop how many seasons and did the purchase of this machine have any impact on your household consumption?)		
Q28	Name of company or person from whom you bought the equipment and where they can be found	*Name*____ *Location*____	
Q29	How did you get to hear or know about this equipment and the seller?		

Q30a	What were the main factors that influenced your decision to buy this particular equipment (brand) and not any other one (List and explain up to 3 factors)		
Q30b	Of the factors that you have listed please state the most important factor which influenced your decision to buy the equipment		
Q31	If you had the opportunity to choose between two tractors of the same price , one from UK and another from China which one will you prefer	*1.....UK* *2.....China*	
Q32	Please explain your answer in Q32		
Q33	Under what circumstances would you have preferred an equipment from China (ask this question if the respondent Chooses UK in Q32)		
Q34	What was the cost of transportation including fuel used to bring your machine home when you bought it?	*TSH*	
Q35	How much money did you spend on maintenance and repairs in the last season	*TSH*	
Q36	Cost of all spare parts you have replaced in the last year (season)	*TSH*	
Q37	How much fuel does this equipment consume per acre?	*Litres: a Ploughing b. Paddling/Harrowing*	a.________ b________
Q38	How many time must the oil be changed during the season	*a. Number b. Volume of oil tank*	a.________ b________
Q39	How much does it cost to change the oil each time	*TSH*	
Q40	Number of times it has broken down in the past one year/season so that you could not use it for work	*Number*	
Q41	Number of days/hours required to fix faults and the amount it costs	*a.. Days b. Cost*	Major Fault Minor Fault a.............. .... b.............. ....
Q42	How much does the repairer charge you for an over haul	*TSH*	
Q43	Ability to work well in very heavy and hard soils without getting damaged (scale 1- very low and 7-very high)	*Use ladder to explain*	
Q44	If someone were to buy a new equipment same as yours, how long do you think he will use it before it starts breaking down frequently?	*years*	
Q45	Length of time your machine can be used from now before you would have to dispose it for a new one.	*years*	
Q46	Do you think your equipment is the best compared to other brands being used by other farmers in this area or community?	*1.....Yes 2.....No*	

Q47	Please explain your answer in 46		
Q48	How much time does this machine take to work on an acre of land in this area?	*Hours: a. Plough b. Paddle/harrow*	a.________ b.________
Q49	Work done in 8 hours on normal soils in this area (acres)	*Acres: a. Plough b. Paddle/harrow*	a.________ b.________
Q50	Work done in 8 hours on hard soils (acres)	*Acres: a. Plough b. Paddle/harrow*	a.________ b.________
Q51	Please rate the quality of ploughing of this machine compared to other similar machines in this area(1-7)	*where 1 is very low quality and 7 is very good quality (a. Plough b. Paddle/harrow)*	a.________ b.________
Q52	Extent of satisfaction with the work that this machine does considering the age of the machine and your soil type (1-7)	*where 1 is not satisfied at all and 7 is very satisfied*	1 2 3 4 5 6 7
Q53	Vibration levels (1-7)	*where 1 is very low vibration levels and 7 very high vibration levels when operating*	1 2 3 4 5 6 7
Q54	Noise levels (1-7)	*where 1 is very low noise levels and 7 very high noise levels when operating*	1 2 3 4 5 6 7
Q55	Smoke levels (1-7)	*Where 1 is very light smoke and 7 is very thick smoke*	1 2 3 4 5 6 7
Q56	Frequency of break down (1-7)	*where 1 is not very often and 7 is very often*	1 2 3 4 5 6 7
Q57	Cost of spares (1-7) compared to other brands	*where 1 is relatively low and 7 is relatively high*	1 2 3 4 5 6 7
Q58	Tell me about the problems or challenges you face as you use this machine *(finding spares, overheating, parts which gets damaged quickly, lifespan, material used for manufacturing the machine, leaking, rusting)*		
Q59	If the work this machine does in an hour were to be done by people with hand hoe, how many people will have been required?	*Number*	
Q60	Level of ease of finding a good operator for this particular machine (1-7)	*1- very easy; 7-very difficult*	
Q61	Length of time required to train someone to operate and do routine maintenance on this machine (Months/Days)	*a. Months b. Days*	a. ________ b.________
Q62	Do you think that the price at which you bought this machine is proportional to the work it is able to do and the quality of the machine?	*1.....Yes 2.....No*	

Q63	Please Explain your answer in Q62		
Q64	Is this equipment appropriate for the kind of work you do (is it fit for your purpose in terms of soil type, availability of spares, ease of operation, quality of work, durability, cost)? (Scale 1-7)	*1 not very appropriate; 7 very appropriate*	Rank
		a. Soil type	1 2 3 4 5 6 7
		b. Availability of spares	1 2 3 4 5 6 7
		c. Ease of Operation	1 2 3 4 5 6 7
		d. quality of work done/Efficiency	1 2 3 4 5 6 7
		e. Durability and quality	1 2 3 4 5 6 7
		f. Acquisition cost	1 2 3 4 5 6 7
		g. Technology in Use	1 2 3 4 5 6 7
		h. Scale of operation	1 2 3 4 5 6 7
		i. Maintenance cost	1 2 3 4 5 6 7
Q65	Please explain your answers in Q64		
Q66	If you were to choose between a tractor or power tiller which would work for 4 years and cost 40% of another which could work for 10 years which one would you prefer?	*1….First Choice* *2….Second Choice*	
Q67	Please explain your answer in Q66		
Q68	Which of the two equipment in your current situation can you afford to buy (Use TSH22m & TSH58 for tractor users and TSH3m & TSH9m for power tiller users as examples)	*1….First Choice* *2….Second Choice*	
Q69	Please explain your answer in Q68		
Q70	Who repairs your equipment mostly when it breaks down mostly? (Write the name of person or company and Location with distance from where you live)	*a. Name________* *b. Location________* *c. Distance (KM________*	
Q71	If it is a dealer who gives you this service, how long does it take for his men to get to you when you ask for their service	*Days*	*a. Minimum________* *b. Maximum________*
Q72	On average how much does such a service provided by the dealer cost per visit?	*TSH*	
Q73	How easily do you find repairers (1-7)	*1- very easy; 7-very difficult*	1 2 3 4 5 6 7

Q74	In the past season how many times was your work halted because the machine broke down and you could not find someone to repair it?	*number of times*	
Q75	In the past season how many times was your work halted because the machine broke down and you could not find spare parts?	*number of times*	
Q76	In the past season how many times was your work halted because the machine broke down and you did not have money to buy spare parts?	*number of times*	
Q77	When you hire a tractor/power tiller out how much do you charge per acre	*TSH: a. Plough b. Paddle/harrow*	a.______ b.______
Q78	How much does the operator charge per acre?	*TSH: a. Plough b. Paddle/harrow*	a.______ b.______
Q79	In the last season how many acres of land did you plough with your equipment on your own farm?	*Acres: a. Plough b. Paddle/harrow*	a.______ b.______
Q80	In the last season how many acres of land did you plough with your equipment on other people's farm	*Acres: a. Plough b. Paddle/harrow*	a.______ b.______
Q81	Did you use the power tiller/tractor for any other activity apart from ploughing or paddling in the last season, and how much money did you get from it or would have got from it if it were to be paid for?	*Activity*	*Amount (TSH)*
		Pumping water	
		Transporting goods	
		Grinding grains	
		Spraying of crops	
		Making ridges or mounds	
		Other (specify)______	
Q82	a. Level of Education of farmer (number of years of completed education) b. Family Size	*Number*	a.______ b.______
Q83	Have you had any training in farming?	*1…..Yes 2…..No*	
Q84	What type of training do you think you will need to operate and maintain your power tiller/tractor? Describe please.		
Q85	How long have you been farming?	*Years*	
Q86	Have you received any extension information about Tractors or power tillers in the past one year?	*1…..Yes 2…..No*	
Q86	What was the nature of information received? Describe		
Q87	From whom did you receive the information? (Name of organization or person)		

Q88	Do your family members work on the farm?	*1…..Yes 2…..No*	
Q89	Number of family members who work on farm	*Number*	
Q90	Payment of family members on Farm	*1…..Yes 2…..No*	
Q91	What is the nature of Payment?	*1….Cash 2….Kind (agricultural produce)*	
Q92	How much per year per person (average), if kind convert to TSH	*TSH*	
Q93	Farm size (acres) all land cultivated in the last season	*acres*	
Q94	In your opinion is your equipment able to do all the work you expect it to do on your farm?	*1…..Yes 2…..No 3….Somehow*	
Q95	Please explain your answer in Q94		
Q96	Do you hire labour for farm work?	*1…..Yes 2…..No*	
Q97	How easily do you find labour during the major season?	*(Scale 1-7)1-very easy; 7-very difficult*	1 2 3 4 5 6 7
Q98	Number of hours worked per day per person during the peak season	*hours*	
Q99	Number of days per season per person (average)	*Number*	
Q100	Total number of persons hired per year	*number*	
Q101	What is the main means of cultivating the land (ploughing)?	*1..Hand hoe 2…Animal Power 3…Tractor or power tiller*	
Q102	What proportion of the work done on the farm is by (…) %	*1..Hand hoe ____ 2…Animal Power ____ 3…Tractor or power tiller r____ (all three should sum up to 100%)*	
Q103	If government were to supply every farmer with a tractor/power tiller which brand will you recommend and why?		
Q104	If government were to supply every farmer with a tractor/ power tiller which brand will you not recommend and why?		
Q105	What do you think should be the price of a tractor/power tiller that many farmers in this area can afford (without trailer and implements) TSH	*a. Tractor…………………………….. b. Power Tiller………………………..*	
Q106	Crop 1 grown	*Crop name*	
Q107	Crop 2 grown	*Crop name*	
Q108	Crop 3 grown	*Crop name*	
Q109	Crop harvest 1	*Unit__________*	Quantity__________

Q110	Crop harvest 2	*Unit*________	Quantity________
Q111	Crop harvest 3	*Unit*________	Quantity________
Q112	Proportion sold of harvest 1	*%*	
Q113	Proportion sold of harvest 2	*%*	
Q114	Proportion sold of harvest 3	*%*	
Q115	If you were to sell all the output from your farm, what would be the value?	*TSH*	
Q116	Soil wetness during the land preparation stage	*1-very wet, 7-very dry*	1 2 3 4 5 6 7
Q117	Soil structure during the land preparation stage	*1-very soft; 7-very hard*	1 2 3 4 5 6 7
Q118	Presence of Gravels on your land	*1-very few; 7-a lot of them*	1 2 3 4 5 6 7
Q119	How far is your farm from the main primary market (where you sell your produce)?	*km*	
Q120	When did you start using tractors on your farm (year)		
Q121	What is the most common tractor being used in this region nowadays	*Brand Name*	
Q122	What is the most common power tiller being used in this area nowadays	*Brand Name*	
Q123	Do you know the reason why people are using the tractor and power tiller you have mentioned above in Q121 and Q122...please tell us		
Q124	What was the size of your farm before you started using tractors/power tillers (acres)	*acres*	
Q125	What is the size of your farm now that you are using tractors/power tillers	*acres*	
Q126	What was the output of your main crop before you started using tractors/power tillers	*Unit*________	Quantity________
Q127	Membership of a cooperative group		
Q128	Name of Cooperative Group		
Q129	Do you think the quality of tractors today is as good as those in the 80s and 90s?	*1....Yes 2....No*	
Q130	Please explain your answer in Q129		
Q131	What do you think is the ideal lifespan of a 65HP tractor (which cost.....) before it starts to give you problems	*years*	a. TSH35m________ b. TSH68m________
Q132	What do you think is the ideal lifespan of a power tiller (which cost....) before it starts to give you problems	*years*	a. TSH10m________ b. TSH3m______
Q133	What do you think should be the price of a tractor/power tiller so that people in this area can afford now and businessmen will not make a loss? (TSH)	*a. Tractor*________ *b. Power Tiller*________	
Q134	At the prices that you have quoted what do you think the quality of the machine will be?	*1-very low; 7-very high*	1 2 3 4 5 6 7
Q134a	Have you heard/know anything about China? (Products, Trade, etc.)	*1....Yes 2....No*	

Q135	Comment on knowledge about China (please write all that the farmer tells you		
Q136	Do you think China's presence in Tanzania has a positive or a negative impact on the country (*1....Positive 2....Negative 3.....Both) Choose an option and explain*		
Q137	Has China made Tanzania worst off or better off	*Scale 1-10 (1-worst; 10-better off)*	
Q138	Any general comments about China?		
Q138a	What lessons can Tanzania learn from China?		

Q138b. Please list all other oxen, power tillers and tractors that you have and are working on your farm apart from the machine we have talked about in this questionnaire

Name/Brand of Animal /Equipment	Number	Proportion of work it does on your farm (%)	Age (Years)

Q139. Please help us to complete this table on spare parts you have bought for your machine in the last season

a. Number	b. Name of spare part	c. Where you usually buy them (location)	d. Distance of point of purchase from where your equipment stationed	e. Average price of 1 in the last cropping season	f. How many days does it take you to get one to buy

Interviewer should write any other comments and some summery of the interview which he thinks can help us explain the information better below, especially on the background of famers. Also ask them if they were to buy a new tractor which type would they buy and why?

*Signature of Respondent*______________